

RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program

Advisory Council Report 2023

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RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program

Meeting of the Advisory Council of the RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS), July 19 – July 21, 2023, Wako, Japan

➤ **Members of the RIKEN iTHEMS-Advisory Council (iTHEMS-AC)**

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➤ **Summary of the 2023 iTHEMS-AC meeting**

The meeting of the Advisory Council (AC) of the RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS) was organized by Program Director Prof. Tetsuo Hatsuda, henceforth the PD, and took place from July 19 to July 21, 2023, in Wako, Japan.

The first day was taken up with an overview of RIKEN-iTHEMS led by Executive Director, Dr. Kohei Miyazono who placed iTHEMS in the larger, RIKEN context, recounting the history of both organizations. He emphasized that iTHEMS had an extremely broad remit and desired not only to produce research of the highest quality but also to foster problem-solving and innovation in Japanese society. Some of this is embodied in RIKEN's "Transformative Research Innovation Platform or TRIP". He summarized the main features of the 2018-2024 Mid- to Long-Term Plan which was organized around data science, life science, sustainable development and building a world-class infrastructure. The PD described the main goals for the review, which were organized around three "Terms of Reference (TOR)":

1. Evaluating the iTHEMS response to the 2019 Advisory Committee.
2. Reviewing the "Strengths-Weaknesses-Opportunities-Threats or SWOT" analysis of the 2018-2024 plan.
3. Anticipating the 2025-2031 plan and assessing the associated strategic planning.

The second day was mostly devoted to scientific presentations, starting with longer presentations by Drs. Kurosawa (theoretical biology), Doi (computational particle and nuclear physics), Fawcett (genome evolution), Yokokura (theoretical physics), Chiu (condensed matter physics), Namba (theoretical cosmology), Iritani (mathematical biology and evolutionary ecology), Cao (algebraic geometry and mathematical physics), Mikami (mathematics) and Inman (theoretical and computational cosmology). These were followed by one minute flash presentations on an even more diverse set of topics followed by a poster session.

All of the AC members enjoyed the presentations in the talks and posters and were greatly impressed by passion of young researchers, their enthusiasm for research, and especially, their brave attitude without any hesitation to talk and discuss with people working on different areas of research. iTHEMS is such a place to provide an excellent interdisciplinary atmosphere under one roof, which is quite rare not only in Japan but also in the world. It is the "strength of iTHEMS" led by iTHEMS senior members.

The third day was mostly taken up with closed discussion between the AC and senior members of iTHEMS, and a committee closed session. The day concluded with an open session where the committee presented its interim impressions to the entire iTHEMS community.

Overall, during three days, the AC members were impressed by the activities of young researchers, as well as the great leadership and vision for the future of the program director (PD) and deputy program directors (DPD).

➤ **Tasks of the iTHEMS-AC**

The AC is tasked with reviewing the activities of iTHEMS planned from 2025 to 2031 and giving a reply to the Terms of Reference for the Center Advisory Council (TOR) as laid out by the RIKEN President.

TOR1: Evaluate the responses to the 2019 AC recommendations.

TOR2: Based on the results of the Center's self-analysis, evaluate operations and R&D activities for the 4th Mid-to Long-Term Plan period (FY2018-2024).

TOR3: Evaluate the policies of the 5th Mid- to Long-Term Plan period (FY2025-2031) and recommend new directions for operations and R&D that should be implemented and promoted.

Executive summary

iTHEMS has sincerely responded to all the recommendations in the 2019 Advisory Committee report, as described in detail below. Based on the recommendations, iTHEMS then constructed various new frameworks such as SUURI COOL satellites in 5 places in Japan, RIKEN-Berkeley Center in US and a special fellowship (RIKEN-Berkeley Fellow) associated with it, and new attempts to educate undergraduate and graduate students at Tokyo, Kyoto, and Nara Women's Universities for recruiting them into interdisciplinary areas of mathematical sciences. These new frameworks boosted research activities of iTHEMS members and collaborations with researchers outside of RIKEN. Consequently, the number of foreign researchers at iTHEMS and international collaborations has increased. This new educational system is expected to encourage young students in Japan to become interdisciplinary researchers and should increase number of women scientists in this area in the future. These new frameworks should foster the exchange of ideas, both globally and between different subjects and societies.

iTHEMS has also strongly supported outreach activities by younger members of iTHEMS through the writing books and presenting scientific talks for the general public. Such activities not only publicize RIKEN and iTHEMS but also broaden the research perspectives of younger researchers.

RIKEN SUURI is another new framework intended to facilitate collaboration with industry, connecting society and the academic world. It enhances human interaction as well as academic and technological collaboration.

The above are only a part of the activities for the 4th Mid-to-Long Term Plan period. It is impressive that iTHEMS has expanded its size and quality of researches for only 4 years after the 2019 AC meeting. It is mostly owing to the hard work of the PD, Tetsuo Hatsuda.

A new era of RIKEN started under the director Gonokami and the RIKEN TRIP (Transformative Research Innovation Platform) began in 2023. This is an ambitious program to harness basic science to help bring about “revolutionary” social change in order to address urgent, global challenges.

RIKEN's Vision on the 2030 Horizon is:

1. Mission

To bring science to the Japanese people and to humanity as a whole, to create their tomorrows through honest dialogue with the people whose values they embody as a national research and development agency.

2. Organization and action

To bring together broad areas of global cutting-edge science and technology engaging the world's most prominent researchers and engineers, without fear of remaking the organizations where they work, identifying the tasks that only RIKEN can tackle, putting into practice the investigations that only RIKEN can undertake.

3. Orientation

To assemble and orchestrate RIKEN's strengths, achievements, and tradition in order to bring science to new heights and pioneer new realms of research in response to rapidly evolving real problems.

4. Recruiting of research talent: Brains Without Borders

To enable the best research minds – from Japan of course, together with the best investigative minds everywhere – to convene and associate with each other and train the next generation of eminent researchers and engineers, instilling in them the aptitude and skills necessary to meet tomorrow's challenges, making RIKEN an ever better setting for sharing exciting new ideas.

5. Industry-society tie-ups

To forge ties between our society and industry through study of the ever-growing range of modern science and technology, from basic research to applications, to determine which direction it should turn next for the better society still under construction.

6. Governance and management

To become more responsive to the needs and aspirations of society and the world by making organizational responses more reliable and adaptable to programs linking desirable research trends to systematic management support promoting such research.

See https://www.riken.jp/en/news_pubs/news/2022/20220817_1/index.html.

The underlined text is especially relevant to the iTHEMS 5th Mid- to Long-Term Plan (FY2025-2031).

iTHEMS leadership in basic and mathematical science plays a large role in realizing the vision of RIKEN, and proposing and developing the TRIP concept. As presented in the meetings, the brains of iTHEMS have no borders, covering wide areas of mathematics, physics, chemistry, biology, and even social sciences. The four wings proposed by the PD, “Nature Wing”, “Technology Wing”, “Life Wing”, and “Society Wing”, will bring science to new heights and pioneer new realms of research. Towards the goal, iTHEMS already organized international workshops and started interdisciplinary collaborations.

iTHEMS also hosts a main project of TRIP, RIKEN Quantum, and plays a core role of organizing it in RIKEN. The flexible theorists within iTHEMS, unconstrained by specific experiments are well suited to this task. This is a strength of iTHEMS.

RIKEN SUURI is a new hub, intended to facilitate collaboration with industry, connecting society and the academic world. It enhances human interaction as well as academic and technological collaboration. iTHEMS is its brain. The Technology Wing (related to RIKEN Quantum) and Society Wing (Prediction science and Blockchain economy) in the future iTHEMS plan will also forge such ties.

Overall, the policies of iTHEMS are consistent with the new vision of RIKEN, and iTHEMS must play a pivotal role when RIKEN undertakes the tasks that only RIKEN can tackle and be the brain of RIKEN activities. However, iTHEMS, in its present form, will not be able to meet this challenge. A significant increase in budget and human resources will be needed. In particular, to keep the inspiring and enterprising atmosphere of iTHEMS for young researchers, iTHEMS will need more senior scientists who can support them through their deep understanding of interdisciplinary research.

The 2023 AC strongly supports the future plans of iTHEMS.

TOR1:

Evaluate the responses to the 2019 AC recommendations

Overall iTHEMS has sincerely and successfully responded to the 2019 AC recommendations, which has benefitted RIKEN. Before commenting on the reactions to each of the recommendations in the 2019 AC review, we recapitulate the conclusion of the previous report:

“The existence of iTHEMS and its activities are very encouraging for the future, because the research environment in Japan tends to embody a short-term vision that makes research planning and activities too uniform, as a Kintaro-ame is, that is, the strength of diversity may be lost. In short, under the present situation of government funding of only a few unexplored areas, we expect iTHEMS to lead the exploration of new and fundamental directions from a theoretical standpoint for the future of humankind.”

The targets of conventional disciplines are specific natural or social phenomena. By contrast, theoretical science, as practiced by iTHEMS, is a flexible way of thinking about different subjects. The scope of theoretical studies has no boundary and no border.

The responses of iTHEMS to the 13 recommendations (from RC-1 through RC-13) of the previous AC in 2019 are based on this spirit. We will comment on each of them in turn.

RC-1: To increase the number of tenured positions for senior leaders

Findings and comments:

In 2020, iTHEMS has appointed one sabbatical-leave researcher, Catherine Beauchemin, (Toronto Metropolitan Univ.) as a Deputy Program Director (DPD), to join the three existing DPDs. The AC found that this managing system functions successfully at the moment. The AC found that the issue of hiring tenured senior leaders is linked to the personnel system of RIKEN and cannot be solved by iTHEMS alone. The AC endorses the future plan of iTHEMS to hire tenured DPD dedicated to iTHEMS activities and also to utilize new “Early Career Leaders (ECL) program”. As iTHEMS has been expanding its size, the role of such senior members is also increasing for organizing the research programs in iTHEMS and for supporting young researchers.

RC-2: Use of cross-appointments and sabbaticals

Findings and comments:

The AC recognizes that iTHEMS appointed Catherine Beauchemin as one of the DPDs on 2020 utilizing her long sabbatical leave to lead the theoretical biology activities. Also, the AC recognizes the appointment of Yasunori Nomura (UC Berkeley) as a Senior

Research Scientist during his summer leave in 2023. The AC endorses the iTHEMS's plan to increase the number of prominent researchers from abroad by utilizing sabbatical or summer leave.

RC-3: To increase the number of junior researchers

Findings and comments:

The AC found the number of junior researchers increases by 1.5 times since the last AC meeting on 2019 and approaches 35 (50 including senior researchers and students) in 2023. However, growth has halted over the last three years because the iTHEMS basic budget from RIKEN has not been increased since FY2020 and stays around 265M JPY/year. The AC appreciates the effort of iTHEMS to expand many activities within the limited budget by receiving ~100 M JPY/year from external sources.

RC-4: To support stipends for the junior researchers working/visiting abroad

Findings and comments:

The AC found the iTHEMS and N3AS Physics Fundamental Center at UC Berkeley agree that N3AS covers the stipend for the RIKEN-Berkeley Fellows during their long-term stay in Berkeley. Also, for other long-term visits, iTHEMS subsidizes the local living cost as a part of travel expenses on top of the salary. The AC appreciates such efforts to support iTHEMS junior researchers working/visiting abroad.

RC-5: To increase the diversity of junior researchers in terms of nationality and gender

Findings and comments:

The AC recognizes that iTHEMS has successfully increased the fraction of non-Japanese researchers from 10% (FY2019) to 48% (FY2023). This increase is partly due to the use of AcademicJobsOnline system which is widely-used international recruitment platform.

On the other hand, the fraction of female researchers remains 5-10% level since FY2019. This is partly because the number of female applicants is typically less than 10%. The mobility of iTHEMS female researchers is very high, and 8 female researchers of iTHEMS have moved to Universities as Assistant or Associate Professors.

The AC endorses the iTHEMS's attempt to open recruitment specifically for females without specifying a particular field which seems to work in attracting female applicants. Also, the AC appreciates the iTHEMS activity with Nara Women's University about the online lectures and RIKEN tours for undergraduate female students, and encourages iTHEMS to continue and expand these attempts. More recommendations to improve the current situation of the shortage of female researchers will be given below.

RC-6: To mentor and monitor the career development of junior researchers

Findings and comments:

Other than the daily interactions at the seminar, lunch times and weekly coffee meetings, the PD meets every junior researchers individually twice a year (FY2020, FY2021) and three times a year (FY2022) to provide more detailed support. The AC found that one-on-one interviews allow for a frank exchange of opinions, and any concerns about the results of the interviews are shared with the DPD and the Coordinators (CD). In addition, PD, DPD and CD are available for various consultations and requests via e-mail, slack, and in person. The AC supports the continuation of this effort and recommends to create a more formal consultation service if necessary.

The AC found that iTHEMS is carefully monitoring the career paths of former iTHEMS researchers (40 have moved to academia and 4 to industry since 2019). The AC found that most of the iTHEMS alumni have been appointed as visiting Research Scientists at iTHEMS maintaining research ties with iTHEMS and exporting the iTHEMS interdisciplinary spirit to other institutions and the AC supports this so as to encourage and inspire the present junior members of iTHEMS.

RC-7: To strengthen the industrial relations

Findings and comments:

The AC found that researchers in mathematical sciences (in particular, AI and quantum computing) from companies are invited to iTHEMS as Visiting Research Scientists to conduct joint research or share information. In FY2023, 8 researchers from 7 companies (DENSO, DENSO IT-Lab., QunaSys, NTT, CyberAgent, Quantinuum (US/UK), 1QBit (Canada)) are appointed. Also, iTHEMS promotes collaborative research with companies through joint research agreements or business consignments: At the moment, 10 companies are involved.

The AC recognized that the newly-launched RIKEN SUURI Corp., which Tetsuo Hastuda (PD) and Shigehiro Nagataki (DPD) had a leading role in establishing, is making strong and profitable connections between the industry and the RIKEN researchers.

RC-8: To expand the academic collaborations and to attract graduate students

Findings and comments:

The AC found that iTHEMS has established 5 domestic SUURI-COOL offices (Tohoku U., Univ. Tokyo, Kyoto Univ., RIKEN Kobe, Kyushu Univ.) and 2 overseas iTHEMS office (LBNL and UC Berkeley).

In particular, the AC found the RIKEN-Berkeley Center was established in 2022 by a joint effort between iTHEMS and N3AS Physics Fundamental Center at UC Berkeley, and the RIKEN-Berkeley Fellow (joint postdoc program between iTHEMS and N3AS) was successfully launched with four junior researchers already appointed. The AC endorses strongly this new scheme to support junior researchers for 3 years in the fields of particle physics, nuclear physics, astrophysics and quantum information science under the international environment.

The AC found further that new ties with specific subfields have been created with 10 domestic Universities and 5 overseas Universities and Institutes as tabulated in Section 8 of the AC Review Materials: e.g. the collaboration on plant genome evolution with Oxford Univ., and the theory-experiment collaboration in hadron physics with LHC ALICE Coll. at CERN. The AC found that those bottom-up collaborations are one of the crucial elements of the iTHEMS activities and encourages iTHEMS to further expand its overseas connections.

The AC found that iTHEMS has accepted 23 graduate students (JRA, IPA, Student Trainee) in FY2018-FY2023 from 11 (8 domestic and 3 overseas) institutions. They are becoming important components in iTHEMS research activities and the AC encourages iTHEMS to keep accepting excellent graduate students who could be leading researchers in mathematical sciences.

RC-9: Promotion of data science as a glue to connect different fields

Findings and comments:

The AC understands that it is difficult to secure a sufficient number of data science researchers in academia. The AC found that iTHEMS has tried to recruit junior researchers in the field of machine learning since 2019 and was successful to hire two junior researchers (one of them has already moved to AIP as a tenured senior research scientist). The AC endorses the iTHEMS's plan to promote the collaborations with RIKEN AIP, RIKEN Research DX Foundation Team under the RIKEN TRIP project.

RC-10: Plan for the future of iTHEMS including its management.

Findings and comments:

The AC recommendation will be discussed in TOR3 section.

RC-11: Improving daily operations of iTHEMS.

Findings and comments:

The AC recognized a flexible and inspiring inter-disciplinary environment is being created through effective and broadening colloquia, seminars, conferences, workshops and coffees.

The AC found that the daily coffee and related costs for smooth interaction between researchers using public donations were not approved by RIKEN, so that Tetsuo Hatsuda continues to provide the support at his own expense.

The AC found that the iTHEMS offices on the 3rd and 4th floors were equipped on the main research building, which partially solved the shortage of iTHEMS's office space. However, the AC noticed that the number of iTHEMS researchers has increased rapidly,

so, in the near future, expanding the office space by converting the adjacent, shared meeting rooms on the 3rd and 4th floors is an urgent need.

The AC also found that an independent promotion office dedicated to iTHEMS recommended by the previous AC report was not realized. RIKEN should consider this urgently.

RC-12: Encouraging outreach activities by junior researchers.

Findings and comments:

The AC found that, in addition to individual outreach activities by junior researchers, iTHEMS has hosted annual public lectures, “The World of Mathematical Sciences” since 2020 and asked junior researchers to give lectures. These lectures have been well received by middle and high school students, university students, and working adults nationwide.

In addition, the AC recognized that 17 books have been published by the iTHEMS researchers since 2017: 6 of them are books for the general public by junior researchers.

The AC encourages iTHEMS to continue these activities to inspire the general public by conveying the fascination of science.

RC-13: Keeping the active role and the research performance of the PD.

Findings and comments:

The PD has worked hard and effectively established iTHEMS and is at the center of operations. He should be commended for his leadership and his willingness to enter into new fields and collaborations. This has come, however, at the expense of his personal research program.

The AC recognized that the PD has been active since 2019 and expanded his scientific scope beyond nuclear and particle physics by working with the junior researchers and writing papers, e.g. in the fields of gravitational wave astrophysics, econophysics and quantum computation.

TOR2:
**Based on the results of the Center’s self-analysis, evaluate
operations and R&D activities for the 4th Mid-to Long-Term
Plan period (FY2018-2024)**

➤ **Center’s self-analysis based on SWOT**

Findings

The self-analysis based on SWOT is very instructive. In summary:

- The Strengths include having grown a well-connected interdisciplinary program “under-one-roof” and extensive network in the world.
- The Weaknesses include the unsustainable dependence on the PD, insufficient budget for growth, far too few women researchers, and a poor fit to traditional RIKEN management.
- Opportunities include increased demand for iTHEMS-style expertise in government, industry, and academia.
- Threats include the nationwide shortage of female researchers and data scientists in academia and insufficient understanding of the importance of basic science in government leaders.

Recommendations

The operations of iTHEMS have successfully extended its Strengths in the flexible and interdisciplinary style of researches as well as the domestic and international research networks. The raison d’etre of iTHEMS is intimately linked with the Opportunities as the importance of mathematical science is becoming more and more recognized as the basic tool for creating a sustainable future for human beings. For overcoming the Weaknesses of iTHEMS, the management system of RIKEN is also necessary to be improved. This is not an easy task but iTHEMS and RIKEN need to work together to solve these problems. The Threats of iTHEMS are more general to the whole sciences in Japan, and even the future of Japan. A flexible institute such as RIKEN should play a leading role in converting Threats into Opportunities.

➤ Governance and management to maximize R&D achievements

Findings

- The PD has presented an ambitious and clear future vision for iTHEMS. (see also RC-13 in TOR1)
- The success of iTHEMS so far is driven by the tremendous efforts of Director Hatsuda. Especially, this is evident from the presentations and discussions with the junior researchers.

Recommendations

- RIKEN needs to consider how to adapt its traditional management style to accommodate a very different organization like iTHEMS, perhaps by seeing it as a RIKEN incubator. (see also RC-11 in TOR1)
- The current organization of iTHEMS is not sustainable. For iTHEMS to remain the brain of RIKEN activities, a new organization, a larger budget and increased human resources are needed.
- To keep the inspiring and enterprising atmosphere of iTHEMS for young researchers, iTHEMS will need more senior scientists who can support them and have deep understanding of interdisciplinary researches to share the vision of the PD. (see also RC-1 and RC-2)

➤ Creation of world's highest level of research results

Findings

All indicators (including publications, awards and seminars) show impressive growth of the research activities of iTHEMS since FY2018. In particular, research results of the present and past Senior Research Scientists (SRS) summarized in Sec.6 of the AC Review Materials have showcased the major success of iTHEMS as shown below.

Biology

Theoretical study of the circadian clocks* (G. Kurosawa)
Origin of buckwheat through genome sequencing* (J. Fawcett)
Noble Population-genetics theory (T. Okada)
Generalized Fisher's fundamental theorem of natural selection (R. Iritani)

Physics and Astronomy

Discovery of a new topological quadratic-node semimetal* (C. Chiu)
Measurement of quantum geometric tensor* (T. Ozawa)
Quantum black hole in semi-classical gravity (Y. Yokokura).
Effective Field Theory with Lorentz Violation (R. Namba)
Radio-Quiet AGN as a Neutrino Production Site* (Y. Inoue)

Computational Physics

Baryon-baryon interactions from Lattice QCD* (T. Doi)
Speed of sound in Dense QCD-like theory (E. Itou)

Mathematics

Yang-Mills theory for Calabi-Yau 4-folds (Y. Cao)

Development of generalized theory of motives (H. Miyazaki)

Lattice Wilson-Dirac index theorem via higher index theory (Y. Kubota)

Data Science

Discriminator optimal transport (A. Tanaka)

Economy

Three-branch structure for Bitcoin transaction network* (Y. Hidaka)

Moreover, many of these works (marked with *) while being theories, have direct relationship to experimental or observational data. For example, the baryon-baryon interactions predicted utilizing the FUGAKU supercomputer simulations by T. Doi et al. have been confirmed later by the high-energy experiments using the Large Hadron Collider (LHC) at CERN.

Interdisciplinary studies emerged from the iTHEMS environment. Examples include: (physicist x economist) “Projecting XRP price burst by correlation tensor spectra of transaction networks”, *Scientific Reports* **13**, 4718 (2023); (biologist x physicist) “Universal constraint on nonlinear population dynamics”, *Communications Physics* **5**, 129 (2022); (mathematician x biologist x physicist) “Structural reduction of chemical reaction networks based on topology”, *Physical Review Research* **3**, 043123 (2021); (biologists x astrophysicist) “Time to revisit the endpoint dilution assay and to replace the TCID₅₀ as a measure of a virus sample’s infection concentration”, *PLOS Comp. Biology* 1009480 (2021).

The collaborative works with industry have been also actively pursued. Some examples are as follows. (IBM x UCB x iTHEMS) “Evidence for the utility of quantum computing before fault tolerance”, *Nature* **618**, 500 (2023); (RICOH x iTHEMS) “Algorithm to visualize changing points of technological trends from literature data”, patent application (2023); (DENSO x iTHEMS) “Hybrid quantum annealing via molecular dynamics”, *Scientific Reports* **11**, 8426 (2021), (JSOL x iTHEMS) “Algorithm for predicting company growth”, (2019-2020), integrated into commercial product called FinCast.

As for the international collaborations, see RC-8 in TOR1.

Other findings

- The research scientists (RS), special postdoctoral researchers (SPDR), and student fellows (JRA and trainees) actively presented their results at their flash talks and posters. Especially, it was impressive to see many of them showing their excitement being a part of iTHEMS.
- There are several examples where it is clear that open discussions and interactions among the iTHEMS members have strengthened the research, demonstrating that the interdisciplinary atmosphere of iTHEMS is instrumental for success.

Recommendations

- Data science has also grown in prominence in recent years, embracing many data-rich subjects represented at iTHEMS. However, recruitment is hard given the competition with industry and it may be better to focus on those areas that interface well with and benefit the existing program. (see RC-9 in TOR1)
- Social science provides another opportunity for a new iTHEMS initiative and should be considered, especially in the context of the TRIP program.
- Engaging mathematicians in an interdisciplinary institute presents a challenge. One device is to use the coffee meetings; another to consider is engaging them in multi-day meetings like the SSP meeting or under the auspices of the RIKEN-Berkeley collaboration. Here, significant problems can be defined in a more mathematical language. Recent successful initiatives involving network reduction and quantum error mitigation have been developed in this fashion and more should be actively started.
- Currently, there is one international hub at Berkeley. Other similar international hubs should be considered, provided that appropriate salary arrangements can be made.
- Dr. Nomura, a senior research scientist who visits over the summer, proposes to lead an initiative on quantum gravity and quantum information theory. Internationally, this is currently an active research area that is not so well represented in Japan. As such it deserves serious consideration by iTHEMS.

➤ Returning research achievements to society, including public relations activities

Findings

iTHEMS has had sufficient outreach activities to return its research achievements to society by public lectures or publishing books.

Here are some of the activities we found:

- Annual public lectures, “The World of Mathematical Sciences” since 2020
Lectures by Junior researchers for middle, high school students, university students, and working adults nationwide.
- 17 books have been published by the iTHEMS researchers since 2017:
6 of them are books for the general public by junior researchers.

Recommendations

Junior scientists need to be given opportunities to understand the importance of explaining their research to society and are encouraged to do this as long as these activities do not put too much pressure on their research.

➤ **Industry-society tie-ups**

Findings (see also RC-7)

The launch of RIKEN SUURI provides a good framework to collaborate with industry. It is a new type of tie-up between societies and academic world, and human interaction as well as academic and technological collaborations are enhanced.

Recommendations

The RIKEN SUURI is an important activity for collaborations with industries and tie-ups with society, but the activity should not put an extra burden on individual researchers. Rather, the activities should be organized to expand the opportunities and vision of iTHEMS researchers. For this purpose, the core personnel researcher specifically assigned to it will be necessary to be hired.

➤ **Recruiting of research talent: Brains Without Borders, Diversity**

Findings (see RC-3,-4,-6)

The iTHEMS leadership in the subject of basic and mathematical science has a large role in realizing the vision of RIKEN, and proposing and developing the TRIP concept. As presented in the meetings, the brains of iTHEMS have no borders, covering wide areas of mathematics, physics, chemistry, biology etc, and even social sciences. The four wings proposed by PD as the policies in the 5th Mid- to Long-Term Plan period (FY2025-2031) are “Nature Wing”, “Technology Wing”, “Life Wing”, and “Society Wing”. Towards the goal, iTHEMS already organized international workshops and started interdisciplinary collaborations in the 4th period.

Recommendations

- The alumni network should be further developed to provide information and opportunities to younger researchers notably in data science.
- iTHEMS should strive to improve the gender balance in its community as a matter of the highest urgency (see also R-5). It is recommended that many different approaches be followed simultaneously. These include:
 - Outreach directed to girls in high school.
 - Making iTHEMS an especially attractive working environment for women.
 - Creating a RIKEN network for women researchers.
 - Working more closely with the RIKEN diversity committee especially on factors that improve work-life balance.
 - Early tenure of well-qualified women researchers should have a big impact on retention.
 - Targeting of senior women scientists already holding permanent positions elsewhere, like Catherine Beauchemin, should be considered.
 - Inviting several candidates for short term visits and being prepared to “buy out” especially strong prospects should be considered.

TOR3:
**Evaluate the policies of the 5th Mid- to Long-Term Plan
period (FY2025-2031) and recommend new directions for
operations and R&D that should be implemented and
promoted**

Findings

Mathematical science (theory, computation, and mathematics) has become increasingly important in the 21st century. The recent rapid progress of quantum computers as well as the generative AI have made even the general public aware of the importance of mathematical science as the basis of these developments. From this perspective, the concept of iTHEMS, established in 2016 with the aim of seamlessly connecting basic science with nature and human activities through mathematical science, is a visionary one.

In FY2016-FY2022, iTHEMS Program has focused on creating an interdisciplinary environment that is attractive to junior researchers in theoretical, computational, and mathematical sciences, and on generating innovative outcomes in this environment, i.e., on building a "Mathematical Science Engine". During the transition period, FY2023-FY2024, iTHEMS will strengthen its efforts toward the establishment of the "iTHEMS Center".

The planned iTHEMS Center starting from FY2025 is expected to serve as a bridge not only between basic sciences but also between basic and applied sciences on a bigger scale. In the new Center, a proper combination of the "Mathematical Science Engine" consisting of the researchers in basic science with the "under-one-roof policy" and the focused research projects called the "Wings" ("Nature Wing", "Technology Wing", "Life Wing", and "Society Wing") is planned. By this new structure, the iTHEMS Center aims at materializing the original concept in 2016; "seamlessly connecting basic science with nature and human activities". It is envisaged that its scope will increase to involve more data science and, perhaps, social science. The industrial and international components would also grow considerably.

To achieve such a transition would require a significant increase in size and budget to a level comparable to other RIKEN centers. Also, much of this plan is tied to the RIKEN TRIP initiative. There seemed to be broad support for this transition within the iTHEMS community although younger researchers were concerned about impairing their career prospects through spreading themselves too thinly and worrying if a lack of focus would hurt their futures. They also seemed to support the proposed expansion into social science. Although some of the activities of the Wings (e.g. RIKEN Quantum) have been already initiated in FY2023, the entire plan from FY2025 was only lightly sketched and, at both the scientific and the administrative levels, had few details beyond the scope and an organization which, while reasonable, seemed likely to evolve.

Recommendations

The committee's prime and unanimous recommendation is to support, in principle, the proposal to transition iTHEMS from a program to a full center. A new "promotion office" should be created to help manage the activities of the new center, including the international hubs, the industrial connections and the outreach activity. This will allow the Director to focus on running the center.

One reason for making such recommendations is that there is clearly a strong need coming from the Japanese government for RIKEN to become much more interdisciplinary and to develop methodologies for combining the expertise of disparate researchers and scientific groups ultimately for the benefit of society with Japan and beyond. iTHEMS is one interdisciplinary part of RIKEN and ideally placed to step up to this responsibility.

The second reason for making this recommendation is that in its brief, five year existence, iTHEMS has been very well led and developed an impressive cohort of young, scientifically diverse and enthusiastic researchers which does collaborate well and effectively. These are good grounds for optimism that iTHEMS is ready to transition to this new level. However, the details must first be developed between RIKEN Management and iTHEMS and carefully reviewed by an independent body familiar with RIKEN. The structure is likely to be framed together with the evolving TRIP concept and data science is likely to be a prominent feature of the plan.

The present management of iTHEMS is not sustainable even with the current scope. A full Program Director, fully dedicated and/or tenured Deputy Program Director(s), and freshly-appointed "Project Leaders" for "Wings" will be needed. This is somewhat in conflict with the original "under one roof concept" of iTHEMS which was so central to its success. However, it does not seem possible for a single leader to oversee and guide so many projects. It is also beneficial to recruit more mathematicians who have the potential to build a bridge between mathematics and other disciplines and will grow into "math interpreters".

Finally, as the Program Director, Hatsuda, also agreed, a strategic recruitment of the next iTHEMS Program Director should be planned and started soon for the smooth transition towards Center and hence the sustainable future of iTHEMS.

Evaluation of the iTHEMS response to COVID-19

As was the case for research organizations around the world, COVID-19 presented immediate challenges. Responsible decisions had to be taken fast on the basis of a paucity of reliable information and contrary direction. It also presents longer term issues as the research environment evolved opening the question of how much of this change will be permanent. This has global implications for the provision of research space, the organization of scientific meetings and the education and support of students. Somewhat related issues are coming up consequent to a much wider awareness of climate change and its implications.

So far as the iTHEMS-AC could see, the response of the iTHEMS leadership was and continues to be exemplary. It took two important measures in 2019: (i) minimizing the risk of COVID-19 spreading at work by improving the office environments, and (ii) providing various new communication tools to maintain communication among researchers within and outside iTHEMS.

In addition, Deputy Program Director Catherine Beauchemin, who is working on viral dynamics, took the initiative of monitoring COVID-19 cases and made the information accessible on a website. This was not only a great help for the iTHEMS members' decision making on COVID-19 measures, but also it is a showcase of how iTHEMS can contribute to tackle an immediate societal problem - part of the RIKEN mission today.

Also, the iTHEMS paid great attention to its researchers' mental condition. After a questionnaire revealed that many researchers needed to be at the office to meet other people, the iTHEMS management developed a policy for safe office usage. Thanks to this, they managed to keep the connection and activity going during the lockdown without having COVID-19 spreading incident. At the meeting, AC recognized that the scientific life was vibrant and healthy and that active communication between iTHEMS members was extremely good. On this basis it recommends that the provision of research space should be at the same level, per researcher, as pre-Covid.

The AC commends iTHEMS for its pro-active leadership at a difficult time.

Evaluation of the synergy of the RIKEN TRIP initiative and the present/future activities of iTHEMS

The RIKEN TRIP (Transformative Research Innovation Platform), which began in 2023, is an ambitious program to harness basic science to help bring about “revolutionary” social change in order to address urgent, global challenges. One of the most pressing social challenges for TRIP is centered on climate change and its irreversible environmental consequences. The iTHEMS leadership had a large role in proposing and developing the TRIP concept and is well-placed to have a foundational role.

iTHEMS conceives its role in TRIP through four “Wings” (Nature Wing, Technology Wing, Life Wing, and Society Wing) serving as a hub for:

- RIKEN Quantum (related to Technology and Nature Wings). This aims to promote quantum computational science across many RIKEN centers engaged in physics, chemistry, and biology.
- RIKEN-Berkeley Center (related to Nature Wing). This combines nuclear astrophysics, particle physics, nuclear physics and quantum information science.
- Medicine and Mathematics platform (related to Life Wing). This connects clinical and basic medicine with appropriate mathematicians.
- Blockchain Initiative (related to Society Wing). This is a longstanding program to use blockchain technology responsibly, reliably and safely.
- More generally, iTHEMS together with TRIP is expected to have a role in prediction science starting with rapidly growing data streams and processing them to make better predictions in general and, ultimately, to benefit society through improving the environment and society.

As the most interdisciplinary organization in RIKEN, iTHEMS intends to create cross-disciplinary value and innovation through the use of theoretical, mathematical and computational sciences. Its successful development of the TRIP initiative is strongly linked to the future of RIKEN.

At this early stage, it is too early to understand how TRIP as a whole, and the iTHEMS role within, will evolve. It is very difficult for the AC to offer much useful advice beyond enthusiastic support for developing the program further. However, there are several questions that should be considered right now.

These include:

- How do the different components of TRIP connect to each other?
- How should the increasingly important artificial intelligence approaches be used across TRIP?
- What new approaches should be emphasized to partner more with industry?
- What are the best channels to use to communicate the results from this program to the government and society at large?
- How can the program attract a more diverse population of junior researchers - the “brains without borders” approach?
- What is the best approach to develop a hybrid Quantum + Classical computing in TRIP?

Conclusion

The AC has reviewed iTHEMS as a vibrant, interdisciplinary theoretical and mathematical science research program. Given the pressing need for answers to urgent problems, as viewed from Japan and globally, there is a very strong case for growing iTHEMS within RIKEN as a Center to provide a general hub for coordinating a much larger program and connecting subfields that do not usually communicate with each other.

Referring to the three Terms of Reference, there has been a good response to the issues arising from the 2019 review. The most conspicuous exception is the failure to significantly increase the fraction of women researchers within iTHEMS and some additional approaches to try to address this disparity should be tried. The AC largely concurs with the SWOT analysis of the response to the 2018-2024 plan. In particular, while it applauds the enormous effort of the PD in growing iTHEMS as originally envisaged, it completely agrees that the current management structure is unsustainable. Looking to the future, there is an urgent need to develop a realistic and affordable plan to make the transition to a new RIKEN Center.

We conclude, as did the last report, with an exhortation to embrace swift action towards a long term vision for iTHEMS and to avoid a conservative and uniform “Kintaro-ame” approach, that is, it may lose the strength of diversity. In short, under the present situation of government funding of only a few unexplored areas, we expect iTHEMS to lead the exploration of new and fundamental directions from a theoretical standpoint.

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The iTHEMS-AC also appreciates the efforts made to present the extraordinary scope of the activities of the iTHEMS carried out under the various Research CELLS during the rapid “flash” talks and the high quality poster presentations. These successfully communicated the breadth and depth of the iTHEMS research program and the enthusiasm with which they are being prosecuted.

The almost invisible implementation of a complex program reflects very favorably on the effective iTHEMS administration. The extensive and clear documentation presented before and during the meeting made the committee’s task much easier and allowed it to focus on larger strategic issues.

The iTHEMS-AC thanks all concerned for a most instructive and enjoyable meeting.