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Chapter- 3

Sustainable Basic Science: New Avenues in Vector Biology and a Novel Artificial Intelligence Paradigm for Research in Public Health

Bishnu Goswami* and Ashis Kumar Panigrahi

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Abstract:

Sustainable research in basic science can be effected more fruitfully with an interdisciplinary scope with a focus on the needs of the general public and penetration to the rural and semirural users, especially in contexts such as public health. Here we have utilised a software based approach for detecting hotspots to curb the menace of mosquito borne diseases. The software module utilises Bongojontro Baksobandi software which was used extensively in past research. The highlights include scopes for incorporating transferable skills to its users, in addition to its primary role in basic research. The initial impression of using the software by high-school users of a rural school and local National Service Scheme (NSS) volunteers was very positive. Future proposals include the use of Artificial Intelligence (AI) models and a pedagogy paradigm for the future learners and researchers.

Introduction:

There are a number of hindrances in the way of sustenance of research in basic science. Although basic science as a subject of graduate study and further research still holds very high acclaim and eminent prizes such as the Nobel prize are given to exceptional researchers, there are still significant problems, such as a gender divide (Tripathi, 2022) and a broader problem with STEM courses and on the topic of the inclusion of minorities (Alexander, 2009; Matz, 2017). Some work, however, is being done to minimize such gaps through inclusive and equitable practices (White, 2021) and using a "systems thinking" approach (Mahaffy 2018).

Developing and newly industrialized countries, one example being India, have additional challenges. These challenges include the lacunae in the development of vocational studies in India, which often contains parts of the subject of basic science, compared to countries like Australia (Sharma, 2018). Secondly, but perhaps no less importantly, there is a need for improved training in public health in India (Tiwari, 2018). Targeting the population itself, even

Bishnu Goswami
Department of Zoology, The University of Burdwan, Burdwan, West Bengal, India
E-mail: bishnu.cert@gmail.com
Orcid iD: https://orcid.org/0000-0002-9473-3947
Ashis Kumar Panigrahi
The University of Burdwan, West Bengal, India
E-mail: provc@gmail.com
***Corresponding Author**: bishnu.cert@gmail.com

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using sophisticated approaches such as algorithmic seeding of social networks, has been tried in at least one of the largest cities in India (Alexander, 2022). However, there are still lots of gaps to fill, especially when the rural and semi-rural parts of the country are to be considered.

In the context of the enemy of mankind, perhaps nothing strikes as more ominous and terrifying than the mosquitoes. Each year, the disease Malaria itself kills over one million people worldwide (Madhu and Sarkar, 2015; Sil et al., 2016; Madhu, 2018; Mubarick, 2021), and mosquitoes are responsible for over one billion cases of diseases in humans (Alar, 2021). One of the most viable ways to reduce the menace of mosquitoes is to target the larval stages of the insect, and various approaches, both physical and chemical have been used, extending in very advanced ways such as oil-based nanoformulations (Esmaili, 2021).

Our research aims to address these three broad areas. The first is to make basic science research more accessible to the masses and rural areas. The second is relating this research to public health so that every stakeholder can potentially benefit. The final is how to facilitate the research in the specific physicochemical analysis keeping the first two areas in mind. The latest development from our research is in the creation of hotspots for physicochemical analysis using a software-based approach. Finally, we're introducing a novel AI paradigm fit for the masses and the future.

Methods:

Making basic research more accessible to the masses, so that they can take up research in their career as an option, or more generally, increase the general awareness about science, is not exactly rocket science. But it is not very simple either. If we consider Maslow's hierarchy of needs, the literature mentions that before a student's cognitive needs can be met, they must first fulfill their basic physiological needs (McLeod, 2007). Before the finer aspects of self-actualization atop the pyramid are met, which research is arguably a part of, the cultural and family expectations need to be met. In many developing and newly-industrialized countries, pressures from the family and local culture come in the way of career selection (Ali, 2017). A common theme among those pressures is the requirement to learn skills that will be useful for the individual's career and for the older members of the population, skills that are directly transferable to career benefits. Amidst this situation, drives such as basic science exhibitions, one-off workshops, and public lectures suffer from the possibility that the intended penetration of their goals will be not met. Unlike specialists, professionals, and students, the interest in research activities is often not a priority for the masses.

Keeping the above paragraph in mind, we had previously developed Bongojonto and Bongojontro Baksobandi, two software modules for general and applied programming and their use by non-programmers. The latter supports various modules that can be used in public-health scenarios (Goswami, 2022). In the latest work, we are using it to detect hotspots for succeeding physicochemical analysis.

As touched upon in the introduction, the larval stages of mosquitoes are easier to neutralize than other stages. These larvae are found in patches, or hotspots, mostly in and around human

habitats. A significant part of the work in vector-borne disease biology is to record the physicochemical parameters of the water bodies in the hotspot zones, and detecting which ones are the hotspots for further analysis can be cumbersome for work in larger areas and for multiple seasons. Here our new module in Bongojontro comes in handy.

Figure 1. With one year/season's data, the model predicts hotspots for the next year or season for physicochemical analyses

Based on database entries of the previous year's larval sampling in the region and on the chemical analysis of the hotspot's water bodies, the module predicts the next year's (or later years, with reduced accuracy) hotspots (Figure 1). These physicochemical analyses, which include temperatures, turbidity, TDS, and concentration of various cations and anions are done by hand using sampled water from the water bodies. Often, the number of water bodies in the study region is too numerous, which makes the work difficult for non-specialists or short-duration research initiatives. In those cases, this hotspot detection software has the potential to be very useful.

The hotspot detection algorithm is based on linear regression models and in the future, we wish to incorporate more advanced machine learning and artificial intelligence models based on even more inputs. We are using a simple linear regression model for now and testing out their usefulness in hotspot detections and succeeding eradication of mosquito larvae to curb the deadly diseases carried by the mosquito vectors.

To impart useful skills and career opportunities, the latter for students, we have incorporated useful skills for a better career in Bongojontro and Bongojontro Baksobandi from the get-go. These include the support of regional languages such as Bengali so that first-time learners can use it. Secondly, the syntax of programming in Bongojontro Baksobandi's modules is such that its users can easily switch to a more established language such as Java or JavaScript (Figure 2). Elaborating on these factors during the demonstration of our software in the context of vector-borne disease elimination proved to be very helpful, at least for the survey participants we had

the chance to be with. These characteristics of the modules make it more enticing for the students and adult participants as they can learn transferable skills from the software which extends much beyond a single-case basic science analysis or applied biology and health analysis.

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Figure 2. A sample program from the Bongojontro Baksobandi module showcasing its simple structure and the transferability of its users to more established languages

Secondly, we introduced a paradigm for the use of AI in vector biology research. With our focus on incorporating a large section of society, and learners in particular, it was realized that restricting ourselves to the advanced aspects of AI was incomplete by itself. Therefore we made a four-tiered AI paradigm in order of the skills of the workers. These tiers were:

Tier 1- Identification of genera and working in the breeding grounds: Fit for inexperienced adults with a short training period and younger students or volunteers. Most useful in developing or newly industrialized countries. Work under this tier includes the collection of larvae of specific genera (associated with spreading mosquito-borne diseases) and live procurement of them to the laboratory.

Tier 2- Creating training datasets: Fit for high school students of science and college students. AI-associated predictions and modelling depends (in most practical cases in the context of vector biology) on creating good training data. Work under this tier includes controlling of the light and environment and the use of smartphones to capture videos of mosquito larvae.

Tier 3- Laboratory work: Fit for undergraduate and graduate students: These usually require a dedicated laboratory environment where precise control of the environment is necessary to grow the larvae or study their various dynamics. Opposed to smartphones, which tend to have over-eager processing, regular cameras (DSLR, Mirrorless or specialised scientific ones) can be used. These are restricted to this higher tier as they have bigger upfront costs compared to smartphones, which are already in circulation and thus, no or little extra cost is needed for their use in vector biology contexts.

Tier 4- Advanced Laboratory work: Fit for research scholars or scientists: These require a laboratory setting and higher experience. Under this tier, work can include working with Convoluted Neural Nets (CNNs)(Promising for larval identification by AI means) and proper utilisation of training and test sets. It was hypothesized that the four tiers can work together in a joint interdisciplinary venture between the students, researchers, various governmental and non-governmental organizations and the common people who suffer from biological vectors like mosquitoes.

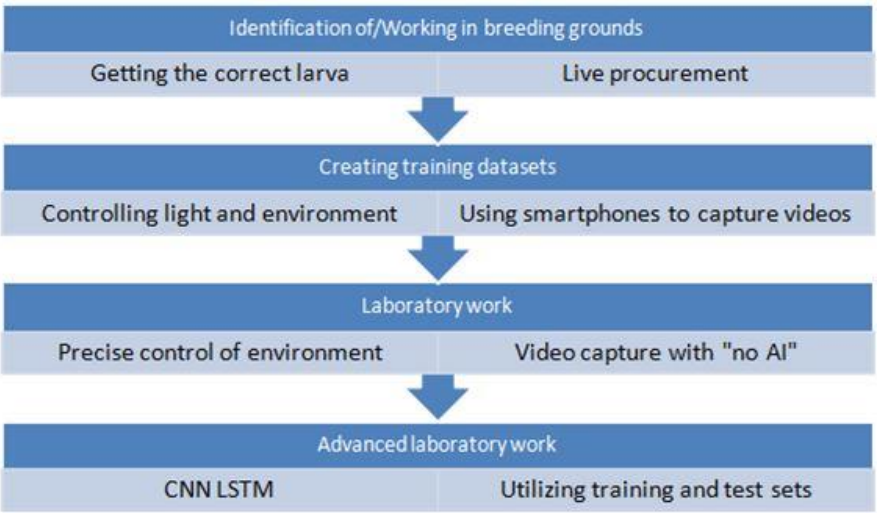

Figure 3. The AI paradigm with increasing levels of sophistication which was introduced to the survey participants

Result & Discussion:

Schoolchildren of the age group 15-17 from a local school and National Service Scheme (NSS) volunteers of India who had previously worked in public health were taken as volunteers and were introduced to the new module and were surveyed on their reception of the software module for in-field usefulness. The total number of survey participants was 56. A survey instrument called the USE questionnaire by Lund (Lund, 2001) was used. Overall, the responses were very positive and hint that further work along these lines can be very fruitful.

Diseases transmitted through vectors present a major concern to human health, hence affecting various parts of the world that are hostile to vectors. The two generic forms of controlling these diseases IRR include insecticides and bed nets, which also have their shortcomings in that they are havoc to the environment besides exerting a high level of resistance. But since their re-emergence, there has been increasing focus on studying their biology and identifying prevention and control strategies that are sustainable. In terms of vectors, one course is devoted to the study of ecology and behaviour (Thiruvoth and Pulikotil, 2017). Scientists noted that comprehending the different factors that affect vector ecology, such as abundance, distribution, and host choice, can help in implementing a focused control strategy. For instance, understanding the mating preferences and behaviors of mosquitoes and their dependence on other species in their environment may inform fledgling techniques that

erode their breeding capability. Finally, in what is probably the greatest development thus far, growth in the fields of molecular biology and genetics brings about new means of vector manipulation. Applying genetic modification through such technologies as CRISPR-Cas9 lets potentially develops sterile or disease-non-transmitting mosquitoes, as well as increasing their susceptibility to control agents. However, ethicists hold that certain parameters should not be crossed, and what impact on the environment in particular could entail is still unknown. Indeed, it is possible to define this paradigm as an efficient theoretical and practical framework in public health empowered by means of appropriate AI tools that may fit the needs and concerns of investigators involved in the public health research process. For example, machine learning algorithms can be trained for surveillance of epidemiological data and derive possible incidences of diseases, thereby enabling authorities to respond promptly.

Also, through the consolidation of information obtained from multiple sources, such as notes on patients, environmental information, and social media posts, AI can offer a broad view of the health status and its causes. The use of big data and related predictive modelling allows the researcher better to understand the high-risk population and direct public health resources most effectively.

Table 1: Part of the results we obtained from the survey.

Statement	Score (1-7)	Standard Deviation
It helps me be more effective	6.02	0.84
It helps me be more productive	4.88	1.23
It is useful	6.26	1.02
It makes the things one would want to accomplish easier to get done	6.14	1.06
It saves me time when I use it	5.18	0.79
It is easy to use	5.06	0.95
It is simple to use	4.35	1.11

Conclusion:

Sustainable basic science research is in high demand for the growth of GDP and other human growth indices throughout the world. However, to reach the masses, both as future researchers and as facilitators of research, requires a more thorough approach. In our work, we have demonstrated that a preliminary software based module can be used for public health research while imparting transferable basic programming skills to its users. The choice of sample collection grounds for chemical and physical analysis was the highlight of our latest Bongojontro module. The initial survey on usability of the software also returned very promising results. In the future, we wish to further explore the interdisciplinary scopes of furthering basic science and scientific research in general. In the context of AI, in the future we are hopeful that better models can be developed which can ensure high accuracy and can be used in conjunction with drones. Although the problems of increasing niches of vectors such as

mosquitoes are likely due to global warming, the application of a sufficiently "intelligent" AI holds the promise for a bright future!

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