

BACHELORS DEGREE IN COMPUTING AND ALLIED FIELDS IN INDIA EMPHASIZING PRIVATE UNIVERSITIES — A STUDY OF SCIENCE PLATFORM (BCA & BSC)

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Abstract

Information and Communication Technology plays a leading role in the development of many facets. Computing and allied educational programs may be treated as a vital source for the development of computerization and digitalization of all kinds. India a nation of ‘developing’ tag needs improvement in the manpower development segment and training. Universities are playing a leading role in building knowledge products, promotion of research & development affairs. As far as Computing and IT areas are concerned in India most popular branches are Computer Science, Computer Application, Information Technology etc. The programs are available with Science platform and also Technology/ Engineering platform. Indian education segment needs much improvement in skill integration into the curricula. A major study found that there are very less differences between Computer Science, Computer Application, and Information Technology curricula. The present study is focused on private universities and highlights the core of Computing programs at Bachelors levels (other than Technology degrees i.e. BE/BTech). The study highlights private university distribution in the Nation with references to emerging skill based Computing degrees as well.

Keywords

Information Systems, Informatics, Manpower development, Computing, BCA Degree in India, Knowledge Economy.

Introduction

Computer is the core of modernization and development these days. Modern nation, state, and local governance needs IT and Computing tools, technologies, and support for the development of each and every facet. Previously in Computing & IT related areas most vital and popular areas was ‘Computer Science’ but in India gradually other domains became popular viz. ‘Computer

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Application', 'Information Technology', 'Computing' etc. It is important to note that there are basic differences in-between Computer Application, Computer Science, and Information Technology but in many contexts the nature of the programs are more or less similar as per curricula study. Computer Science is a theoretically focused domain and mainly concentrated on inner areas of Computers, Hardware etc [1], [5]. It is mathematical in nature and thus most suitable for the research organization and scientific areas of industries. Whereas Computer Application has been started keeping in mind industries and organizations, institutions etc. Computer Application programs were started in India in the 1980's as a substitute of Computer Science to cope up industries demand and prepare skill manpower in Industries.

Internationally Applied program was started 'Information Technology' other than Computer Science. While India was slow in that context. But gradually in India various universities, research centers and organizations have started many areas of Computing/IT. The present study finds out the emerging Computing degrees available in India [2], [4], [12]. The study conducted to break a misconception about availability of Computing Degree means Computer Application (BCA)/ Computer Science (BSc). It is about more than that and includes broader area viz. Information Technology or smaller area viz. Computing/ Cloud Computing etc [3], [6], [12].

Objective & Methodology

The core aim and objective of this conceptual-theoretical work include the following (but not limited to the)—

- To learn about the basics of Higher Education Systems in India with references to university education.
- To dig out the knowledge of Computing and allied fields viz. Computer Science, Computer Application, Information Technology etc.
- To learn about the available programs in the areas of Computing and Information Technology as far as India is concerned with reference to Bachelors programs (other than Technology/ Engineering programs).
- To learn about the emerging skill based Bachelors degree programs available in Private Universities in India.
- To find out possible challenges and future potentialities as far as Computing and Information Technology education is concerned.

To conduct the present study several measures have been undertaken viz. conduction of literature review including web review to study the areas of Computing, Computer Science, Computer Application, and Information Technology [7], [10], [13].

Web review has been also undertaken to learn about the potential universities offering the programs. Hence official website (www.ugc.ac.in) of University Grants Commission (UGC) has been used to reach other private universities [8], [9], [13].

Computing, IT, Allied Field and India

In Computing and Information Technology segment most popular subject is Computer Science, Computer Application, and Information Technology. It is worthy to note that though these subjects having different nomenclature but there are many differences as far as international context [7], [11], [14].

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The branch Computer Science is having fundamental in nature and deals with the core of computing and internal affairs, it is highly mathematical and statistical in nature [11], [15-21], [22]. It is moreover deals with the areas viz.

- Computer Architecture
- Operating Systems
- Numerical Methods & Statistical Techniques
- Artificial Intelligence & Expert Systems
- Machine Learning and Deep Learning
- Image Processing
- VLIS & Embedded Systems
- Software Engineering
- OOPS/ Programming Languages etc.

Whereas Information Technology is purely applied in nature and having a strong foundation of business and organization etc. It is mainly concentrated all kind of other technologies (*as Computer Science branch mainly cares about Computing Technology*) viz. Software Technology, Network Technology, Database Technology, Multimedia Technology, Web Technology etc. However, the branch Computer Application is mainly concentrated on Software Technologies first with the core focus on different kind of programming languages (frontend and backend tools) viz. C, C++, C#, Visual Basic, Java, .Net Technologies etc. Moreover recently Computer Application is also focusing on more popular programming viz. Python, Ruby, R Programming, Perl etc. The emergence of Big Data and Data Analytics lead the affiliation of these popular areas for the intelligent information systems creation and development [7], [22].

As far as Computer Application is concerned, this is the popular branch and areas of study in India whereas worldwide after Computer Science branch Information Technology gained rapid popularity [14], [23].

The branch of Information Technology is most popular in different context and offering flexibility of various areas of research and study viz. Software Technology, Network Technology, Database Technology, Multimedia Technology, Web Technology. Hence in IT special focus may be any one or two above based on student's interest.

Nature of Degrees in India with reference to Bachelors Degrees in IT field

In India Computing and Information Technology Degrees are available with following nomenclature as far as Science platform is concerned (other than Engineering and Technology).

Computer Science

Computer Science branch is offered with the Science degrees viz.

- **BSc-Computer Science**
- MSc-Computer Science
- MPhil-Computer Science
- PhD-Computer Science

Computer Application

Computer Application branch has been started in India with focus on Software Technologies and its application with Science equivalent nature and focus of following degrees (viz.)

- **BCA**

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- **BSc-Computer Application**
- MCA
- MSc-Computer Application
- PhD-Computer Application

Information Technology

Information Technology is available as a branch and also offered with the Science degrees viz.

- **BSc- Information Technology**
- MSc- Information Technology
- MPhil- Information Technology
- PhD-Information Technology

Though these IT degrees have started about 20 years back in India but the nature of the programs still more or less similar to Computer Application i.e. Software Technology concentration ignoring other domains viz. Network Technology, Database Technology, Multimedia Technology, Web Technology. Even business focus is also limited and rarely available in Indian IT degrees.

Information Science

Information Science is another concentration available worldwide having all the components of IT and additionally special focus on Business and Management, Social Applications, Information Fundamentals. Information Science in India available with MSc but with the nomenclature of BSc is hardly available (except BSc-Information Science & Telecommunication at the Ravensaw University, Odisha, India) as far as this study is concerned.

Software Engineering

Software Engineering is another domain which concentrated on the Software Technologies and Programming (OOPS). In India, BSc-Software Engineering is available only in Private Colleges under State & Deemed Universities. As far as this study not a single Private Universities among 279 offers BSc-Software Engineering.

Emerging Skill based Major/ Concentration

Apart from Computer Science, Computer Application, and Information Technology in recent past few important changes noticed in IT & Computing segment. That is specialized programs/ major/ Hons. in the areas of Computing. These are—

- Cloud Computing
- Mobile Application
- Information Security
- IT Infrastructure Management
- Big Data Technologies etc

Importantly all these are offered as a specialization of Computer Application (and rarely IT) programs while worldwide these are treated as sub-fields of IT (rather CA or CS).

Bachelors Programs in CA Concentration

India is one of the leading education hubs in the world and moving towards a developed nation. As a whole India has over 40,000 Higher Educational Institutions in short called HEIs. And all

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these constitutes with the Universities, Colleges, Research Centers, Institutes of National Importance (INIs), Autonomous Institutes and so on.

Regarding Computer Application program it is important to note that most common is BCA (Bachelor of Computer Applications) with 3 years duration. It is available mainly in affiliating universities and professional colleges. While Computer Science is opened for the knowledge seekers from Science branches but the Computer Application (BCA) is offered to all 10+2 irrespective of branches (some also seeks Mathematics/ Computer Application/ Relevant Area as a studied paper at 10+2).

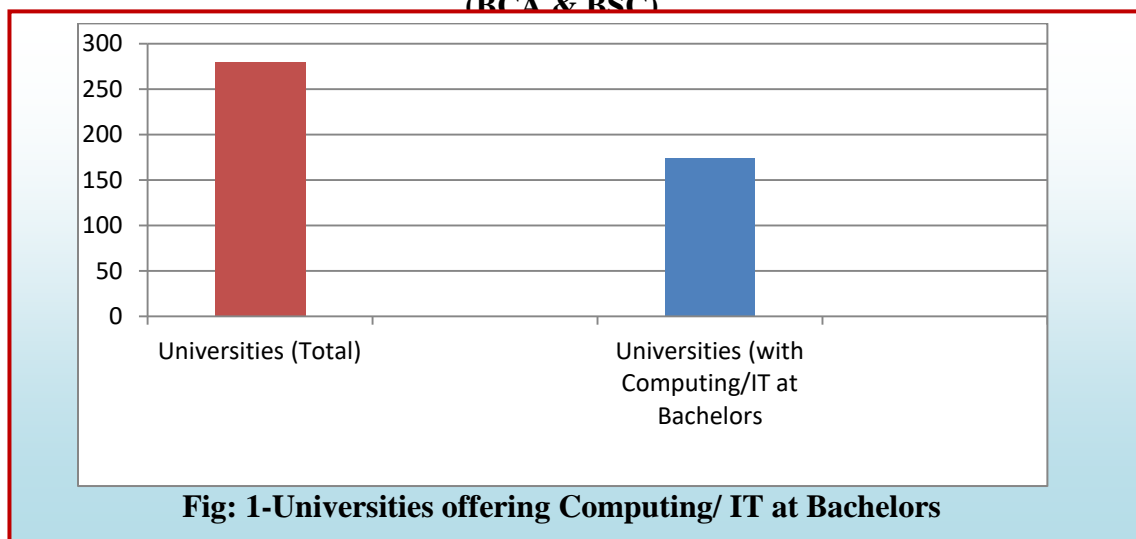
India as a whole has total 279 Universities (as of October 2017) and among these highest are from Rajasthan. The Table: 1 listed here with the details of private universities. In most of the private universities, common subjects are Computer Science, Computer Application, and Information Technology [16-21]. The table: 1 listed all these in brief (state wise).

Table: 1 Private Universities & BSc/BCA in Computing areas

Serial No.	States	No. of Universities	Universities with Computing Programs (BSc, BCA etc)
1	Arunachal Pradesh	7	05
2	Assam	5	04
3	Bihar	2	01
4	Chhattisgarh	9	04
5	Gujarat	30	13
6	Haryana	20	13
7	Himachal Pradesh	17	10
8	Jharkhand	7	03
9	Karnataka	14	05
10	Meghalaya	8	05
11	Mizoram	1	01
12	Madhya Pradesh	24	17
13	Maharashtra	9	06
14	Manipur	1	01
15	Nagaland	3	02
16	Odisha	4	01
17	Punjab	15	12
18	Rajasthan	46	26
19	Sikkim	5	04
20	Tripura	1	01
21	Uttar Pradesh	29	25
22	Uttrakhand	13	09
23	West Bengal	9	06
Grand Total		279	174

It is noticed that Uttar Pradesh holds the highest percentage of Computer related degree offering where out of 29 universities 25 are with Computing degree at Bachelors level. While number wise—*Rajasthan* holds first position at 26 (universities) out of 46 universities. As a whole, 174 universities are offering Computing related Bachelors programs out of 279 universities. Refer Fig: 1 for more clarification.

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Most of the universities among these are offered BCA program i.e. Computer Application and among these highest numbers are from Uttar Pradesh (22 offers BCA out of 29 universities).

Table: 2 Private Universities & BCA Programs

Serial No.	States	No. of Universities	Universities with BCA Only
1	Arunachal Pradesh	7	04
2	Assam	5	04
3	Bihar	2	01
4	Chhattisgarh	9	07
5	Gujarat	30	12
6	Haryana	20	12
7	Himachal Pradesh	17	10
8	Jharkhand	7	03
9	Karnataka	14	05
10	Meghalaya	8	05
11	Mizoram	1	01
12	Madhya Pradesh	24	17
13	Maharashtra	9	06
14	Manipur	1	01
15	Nagaland	3	02
16	Odisha	4	01
17	Punjab	15	12
18	Rajasthan	46	26
19	Sikkim	5	04
20	Tripura	1	01
21	Uttar Pradesh	29	22
22	Uttarakhand	13	09
23	West Bengal	9	06
Grand Total		279	171

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While Manipur has total 1 university and it has started BCA program (the same statistics also for the state of Tripura). In Punjab, total 12 Universities out of 15 are offering BCA programs. As far as West Bengal is concerned it is about 75% (9 out of 6 universities).

Bachelors Programs in Science Concentration

As far as other stream and areas are concerned (other than Computer Application) the statistics are like this—Uttar Pradesh holds the first position with 14 Universities offering BSc nomenclature (maybe on IT/ CA/Computer Science). Though few states offer BSc course but it is very minimum compared to others viz. Odisha, Gujarat, Haryana. A detailed profile has been provided in Table: 3 for more clarification.

Table: 3 Private Universities & BSc Programs

Serial No.	States	No. of Universities	Universities with IT Other Degrees (Bachelors)
1	Arunachal Pradesh	7	04
2	Assam	5	02
3	Bihar	2	01
4	Chhattisgarh	9	04
5	Gujarat	30	07
6	Haryana	20	07
7	Himachal Pradesh	17	01
8	Jharkhand	7	02
9	Karnataka	14	01
10	Meghalaya	8	02
11	Mizoram	1	00
12	Madhya Pradesh	24	11
13	Maharashtra	9	03
14	Manipur	1	00
15	Nagaland	3	01
16	Odisha	4	01
17	Punjab	15	09
18	Rajasthan	46	12
19	Sikkim	5	03
20	Tripura	1	01
21	Uttar Pradesh	29	14
22	Uttrakhand	13	05
23	West Bengal	9	01
Grand Total		279	92

As a whole, all over India 92 Universities offers BSc degrees/ programs out of 279 private universities. Interestingly in few states, though BCA is available but BSc degree is still absent viz. Mizoram, Manipur (please refer Table: 4).

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Table: 4 Private Universities & BSc-IT/ BCA Programs

Serial No.	States	No. of Universities	BSc IT	BCA
1	Arunachal Pradesh	7	04	04
2	Assam	5	02	04
3	Bihar	2	01	01
4	Chhattisgarh	9	03	07
5	Gujarat	30	06	12
6	Haryana	20	03	12
7	Himachal Pradesh	17	01	10
8	Jharkhand	7	02	03
9	Karnataka	14	01	05
10	Meghalaya	8	02	05
11	Mizoram	1	00	01
12	Madhya Pradesh	24	08	17
13	Maharashtra	9	01	06
14	Manipur	1	00	01
15	Nagaland	3	00	02
16	Odisha	4	01	01
17	Punjab	15	07	12
18	Rajasthan	46	11	26
19	Sikkim	5	03	04
20	Tripura	1	00	01
21	Uttar Pradesh	29	06	22
22	Uttrakhand	13	05	09
23	West Bengal	9	00	06
Grand Total		279	67	171

Private Universities are also doing well in terms of starting new age programs. Among the broad computing fields important are Information Technology worldwide while India is getting slow in this context. Many universities have started now BSc-IT program. Rajasthan holds first position with 11 programs then second position achieved Madhya Pradesh (total 8 programs), third goes to Punjab. Though, it is important to note that while many universities have both BSc and BCA Degrees but still many universities have only BCA programs. Interestingly among these some are big states viz. Mizoram, Manipur, Nagaland, Tripura. While in West Bengal out of 9 universities 6 are offering BCA but no one offering BSc-IT.

Collaboration and Bachelors Degree (Science Platform)

These days universities are changing their traditional style of education and also come-up with various other degrees most of these are new age areas/ sub-fields of Information Technology such as—

- Big Data/ Data Analytics/ Data Science (within Database Technologies)
- Cloud Computing/ Security Technologies (within Networking Technologies)
- Animation/ 3D Technologies (with Multimedia Technologies) etc.

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Surprisingly though these are the areas of Information Technology but offers in the Degrees of Computer Application (as BCA Major/ Concentration/ Honors). The details on this has been analyzed and reported in Table: 5.

Table: 5 Private Universities with emerging skill based specialization/ major with BCA

Serial No.	Universities	Programs
1	Assam Down Town University	BCA Cloud Technology & Information Security (Science)
2	Srinivas University	BCA (Data Analytics & Cloud Computing)
3	Mandsaur University	BCA (Cloud Computing)
4	Sandip University	BCA- Cloud Technology & Information Security (10+2 with Math)
5	Chandigarh University	BCA (Information Security & Cloud Computing)
6	Poornima University	BCA (Mobile Application & Information Security-10+2 with Science/
7	Sikkim Manipal University	BCA (Cloud Technology & Information Security)

However few universities have rightly preferred Information Technology umbrella and few of these are include Assam Down Town University, Centurion University of Technology and Management, Poornima University. Importantly including BCA/BSc-IT specialization few offered the degree for all 10+2 holders (Refer table: 6 for more clarification).

Table: 6 Private Universities offering new age skillful degrees with BSc-IT

Serial No.	Universities	Programs
1	Assam Down Town University	BSc-IT (Information Security & Mobile Applications) (With Math)
2	Centurion University of Technology and Management	BSc-IT (Cloud Technology & Information Security)
3	Poornima University	BSc-IT Infrastructure Management & Cloud Technology-10+2 Any)

Findings

- In generally Computer Science is a fundamental computing degree with theoretical and mathematical concentration, while Information Technology is about applied concentration.
- Computer Application is the Software and programming centric programs. Interestingly it has started in India and still not available other parts of the world. Worldwide IT is treated as organization centric specialization.

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- In India first MCA was started in 1980's gradually BCA programs with aim of students from diverse discipline. But still in most of the universities Mathematics (at least one paper/ course) is the eligibility criteria. While rest of the world, IT is there and in most cases offers an opportunity to enter IT & Computing world from a diverse background.
- Though in some of the Universities Computing (BA) programs started in recent past for the candidates of any stream (refer Table: 7).
- Interestingly due to the need of the hour and importance of emerging areas few areas have been stated viz. Cloud Computing, Information Security, Big Data Technologies, Animation etc. And many of these are offered with BCA/ BSc IT concentration.

Table: 7 Private Universities offering broad but different program

Serial No.	Universities	Programs
1	Team Lease Skills University, Gujarat	BSc-IT Infrastructure Management Service
2	A.K.S. University, Madhyapradesh	BA-Computing (10+2 Any)
3	Dr. A.P.J. Abdul Kalam University, Madhyapradesh	BA-Computing (10+2 Any)
4	Sri Satya Sai University of Technology & Medical Sciences, Madhyapradesh	BA-Computing (10+2 Any)

Conclusion

The world is moving towards a Digital Space. Everywhere Digital Technologies become a vital for the modernization whether it is Healthcare, Agriculture, Education, Government, & Administration. To reach a nation with 'Digital' tag we need to utilize computing and Information Technology significantly. Universities need to care their offerings through more diverse programs and fields of study. At Bachelors level BCA, BSc-Computer Science, and BSc-Information Technology are widely offered as far as India is concerned. Though as Computing and Information Technology are everywhere, thus universities gradually may move on offering programs on other domain centric Information Science programs as well viz. Health Information Science, Geo Information Science, Business Information Science, Chemical Information Science, Bio Information Sciences etc. Though few emerging programs been noticed by few of the universities (viz. Assam Down Town University, Srinivas University) on skill based areas but in general Information Science programs and domain centric programs are highly solicited.

Reference

- [1] Agarwal, P. (2007). Higher education in India: Growth, concerns and change agenda. *Higher Education Quarterly*, 61(2), 197-207.
- [2] Altbach, P. G. (1993). The dilemma of change in Indian higher education. *Higher Education*, 26(1), 3-20.
- [3] Brittain, J. M., & Norris, A. C. (2000). Delivery of health informatics education and training. *Health Information & Libraries Journal*, 17(3), 117-128.
- [4] Eysenbach, G. (2000). Consumer health informatics. *British medical journal*, 320(7251), 1713.

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- [5] Gupta, D., & Gupta, N. (2012). Higher education in India: structure, statistics and challenges. *Journal of education and Practice*, 3(2).
- [6] Kapur, D., & Mehta, P. B. (2004). Indian higher education reform: From half-baked socialism to half-baked capitalism. *Center for international development working paper*, 103.
- [7] Huang, Q. R. (2007). Competencies for graduate curricula in health, medical and biomedical informatics: a framework. *Health Informatics Journal*, 13(2), 89-103.
- [8] Haux, R. (1997). Aims and tasks of medical informatics. *International journal of medical informatics*, 44(1), 9-20.
- [9] Martin, S.B. (1998). Information technology, employment, and the information sector: Trends in information employment 1970–1995. *Journal of the American Society for Information Science*, 49(12), 1053–1069.
- [10] Michael Buckland and Ziming liu (1995). History of information science. *Annual Review of Information Science and Technology*, 30, 385-416.
- [11] Ouzounis, C. A. (2012). Rise and demise of bioinformatics? Promise and progress. *PLoS computational biology*, 8(4), e1002487.
- [12] Paul, P.K., Ashok Kumar, Dipak Chatterjee (2012). Health Informatics and its Practice: Emerging Domain of Information Science-Indian Scenario. *Current Trends in Biotechnology and Chemical Research*, 2 (2), 83-87.
- [13] Paul, P.K., D Chatterjee, M Ghosh (2012). Medical Information Science: Emerging Domain of Information Science and Technology (IST) for sophisticated Health & Medical Infrastructure Building — An Overview. *International Scientific Journal of Sports Science*, 1 (2), -104.
- [14] Paul, Prantosh Kumar (2013a). Information' as Term: Historical Root, Present Focus and Future Potentials with Technologies. *International Journal of Social Science*, 2 (2), 227-236.
- [15] Paul, Prantosh Kumar (2013b) Service Science [SS]: Emphasizing Role of Information Science [IS] as Service Science. *Journal of Information Technology and Engineering*, 4 (2), 61-65.
- [16] Paul, P. K., Aithal, P. S., (2017). Bio-Informatics in private universities in India: An Emerging Study on promotion of Biological Information Sciences. *International Journal of Bioinformatics and Biological Sciences*. 5(1), 1-7.
- [17] Paul, P. K., Aithal, P. S., Bhuimali A. (2017). MCA (Information Science and Management) : The Next Generation Interdisciplinary specialization for Social, Business, Health & Mathematical Sciences—A Step for promoting Digital Humanities. *International Journal of Scientific Research in Mathematical and Statistical Sciences*, 4(5), 27-32.
- [18] Paul, P. K., Aithal, P. S., Bhuimali, A. (2017). Computing & Allied Engineering Domain in India with reference to Private Universities: A Case Study of Bachelors Programs. *International Journal on Recent Researches In Science, Engineering & Technology*, 5(11), 51-63.
- [19] Paul P. K., Aithal P. S., Bhuimali A. (2017). Computing & Information Related Degrees worldwide & India—An Analytical Policy Research. *Educational Quest: An Int. J. of Education and Applied Social Science*: 8(3), 657-666.

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- [20] Paul, P. K., Bhuimali, A., Aithal, P. S., Rajesh R. (2017). Information Science and Technology (IST): The nature and view from the Domain of Computing, Humanities, Management and Engineering—*A conceptual Techno-Educational Study*. *Scientific Review*, 3(9), 77-82.
- [21] Paul, P. K., Bhuimali, A., Aithal, P. S. & Chatterjee, D. (2017). M.Tech-Information Science and Technology (IST): Possibilities and challenges with proposed Five Year Integrated model for building Technology Vis-à-Vis Society. *International Journal of Information Science and Computing*, 4(2), 57-63.
- [22] Supe, A., & Burdick, W. P. (2006). Challenges and issues in medical education in India. *Academic Medicine*, 81(12), 1076-1080.
- [23] Williams, J. J., & Teal, T. K. (2017). A vision for collaborative training infrastructure for bioinformatics. *Annals of the New York Academy of Sciences*, 1387(1), 54-60.