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Importance of Spirit of Inquiry in Engineering Education

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Abstract: This work is a study into the necessity of scientific temperament in engineers. It aims at the study of general trends in engineering education through time, from the point of view of scientific spirit – curiosity, experimentation, repeatability and precision. Here, an undergraduate degree comprising both science and engineering is proposed, and the same is examined from various perspectives, which are arrived at on the basis of statistical evidence.

The study conducted (survey) clearly establishes the need to bridge science and engineering.

The survey was based on four criteria - performing experiments, student bodies (technical clubs), external sources for learning, and pure science subjects taught in engineering. More than 60% of the survey-takers, i.e. students, converged on the need for an undergraduate degree comprising science and engineering. Some important specifications of such a degree, shaped from the survey, are as follows: Its duration can be about four years; research and skill development should be its primary focus; all engineering institutions have to offer it.

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1. Literature Review: Innovations in education must happen simultaneously along two verticals – teaching and learning. This, in tandem with structured programmes, taking into account the views of students, is the need of the hour. The analysis of previous studies in this domain has been instrumental in guiding the subject of this paper.

Inquiry refers to the activities of students in which they develop knowledge and understanding of ideas and draw informed conclusions.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. [1]

Shulman stated that practising inquiry-based learning based on different classroom contexts is a good try to help students. A friendly learning environment for students is necessary for inquiry. The experience of inquiry-based learning can generate students' interests in Science. [2]

Gordin and Pea pointed out three goals students can achieve from inquiry in science education: 1)

learning how to pose researchable questions, 2) learning how to investigate questions using authentic practice, 3) developing a deeper understanding toward Science. [3]

Bybee stated that inquiry-based learning contains three main parts. First, it develops students' scientific inquiry competences. Second, it makes students understand the nature of scientific inquiry. Third, it helps students acquire knowledge of Science. Scientific inquiry is student-centered learning. Through it, students establish scientific concepts. 'How to learn' and 'learning how to learn' are major issues in scientific inquiry-based learning. [4]

Related researches prove that students can acquire a better understanding toward the context and process of science through inquiry-based learning.

Science and Technology: Prof P. Balaram is of the opinion that - Science and technology are inextricably linked, yet they are divided by a chasm which is sometimes difficult to bridge. Public understanding of science and technology is clouded by many misconceptions, some of which are of little consequence, while others are more 'mischievous'.

He also feels that, in India, the lines dividing science and technology have, traditionally, been drawn very sharply. Even at the level of governmental policy statements, the divide is emphasized by the existence of two distinct enunciations of national intent — the Science Policy Resolution of 1958 and the Technology Policy Statement of 1983. The former recognized that 'technology can only grow out of the study of science and its applications', while the latter emphasized the need for 'the development of indigenous technology and efficient absorption and adaptation of imported technology appropriate to national priorities and resources'. Science, to most people, seems to embody the 'pure' sciences taught in colleges and universities and researched in quiet and unobtrusive institutions. Very few realize that connections may exist between scientific research and the teaching of science on the one hand and the many practical and seemingly obvious advantages of applicable advances in science, on the other. Technology is more clearly perceived and assessed. Technology, in the public mind, is associated with engineering. [5]

Innovative technology, which politicians and policy-makers clamour for, can only be born by a fusion of good science and engineering. The rapidly emerging fields of nanotechnology and biotechnology may be advanced only by a 'broad coalition' of scientists and engineers. For this to happen there must be a greater appreciation of science in our departments of engineering, while students of science must be aware of the enormous gulf that engineers bridge, when they transform a scientific advance into a technological success. This coalition must be spearheaded by interpreters who speak both languages. I suspect that it might be easy to find the 'scientists' amongst engineers, who can indeed forge such a coalition, the need for which is being more widely felt in the best of our institutions. The science of engineering requires greater exposure. [6]

Engineering Sciences: Educators in Harvard University believe that - Engineering has evolved over the years to not only dive deeply into specific fields, but also to seek out solutions to real-world problems by combining concepts from a broad range of scientific inquiries and innovations. For example, robotics is a highly interdisciplinary field that straddles multiple traditional engineering disciplines such as mechanical, electrical, and materials engineering and computer science. The Engineering Sciences concentration is ideally positioned to provide students with both the breadth and depth of study needed to excel in various integrative areas of engineering and basic sciences. [7]

The goal of the program (Engineering Sciences) is to develop the student's ability to think analytically across disciplines and tackle future technical challenges that require a thorough understanding of a discipline in the physical sciences and/or mathematics combined with engineering. [8]

The analytical skills, numeracy and practicality developed by Engineering Science graduates are sought after in both industry and commerce. Many continue into a career as a professional engineer while others enter business areas such as management consultancy or finance. Around 30% go on to further study following their degree. The Engineering Science programme is a four-year course, leading to the degree of Master of Engineering. The first two years are devoted to topics which we believe all Engineering undergraduates should study. In the third and fourth years there is scope for specialisation into one of six branches of engineering: Biomedical, Chemical, Civil, Electrical, Information and Mechanical. Decisions about which of these will be

your specialisation can be deferred until the third year. In the fourth year there may be opportunities to study abroad. [9]

At the Indian Institute of Science a unique 4-year Bachelor of Science (Research) programme is offered. The graduates of this programme will obtain a Bachelor of Science (Research) degree in a specialization. This programme is carefully designed to offer specialization in a science subject, but the knowledge imparted carries a strong flavour of engineering and an exposure to social science disciplines. Students specializing in a Major subject are encouraged to take courses on other subjects, thus maintaining the strong interdisciplinary flavour of this Bachelor of Science (Research) programme. All students take core courses in Physics, Mathematics, Chemistry, Biology, Engineering and Humanities in the first one and half years (I, II and III semesters). While specialization is introduced rigorously in the following year and a half (IV, V and VI semesters), the students are free (and are also encouraged) to choose electives from subjects other than their own specialization during this time. The course culminates with a research oriented project in the fourth year (VII and VIII semesters) supervised by a faculty. This programme is embedded in an ambience of a mature and highly sophisticated research culture which has an equally strong base of both science and engineering. This research culture has evolved over the last hundred years, primarily engendered by a highly distinguished faculty, graduate students and post-doctoral fellows.

It has grown in an open and free academic environment where dedicated teaching, state-of-the-art laboratories, fast information networks and well-stocked libraries have come into being, aided by a flexible and enabling mode of administrative functioning. We believe that this unique academic environment should be utilized to impart high-quality training to inquisitive young minds at the undergraduate level. [10]

2. Methodology: About 335 students pursuing their pre-final and final years of the Bachelor of Engineering undergraduate programme in top engineering institutions in Bengaluru, India, were the subjects of a survey. Out of them, 49% were from BMS College of Engineering. 52% of the subjects were in their final year and the remaining in their pre final year of the B.E course. These students were required to answer a questionnaire consisting of 18 questions, which encompassed the parallels aiding classroom learning, like - performing experiments, technical student bodies and additional reading; and also the relevance of pure science courses in engineering education. The necessity and attributes of an integrated Science and Engineering undergraduate degree were also questioned. The online version of the questionnaire was shared on various social platforms and a hard copy of the same was filled by the subjects of the survey. The duration of the survey was ten days.

Students of pre-final and final years of engineering were preferred because of their better understanding of the state of the current engineering curriculum and the need for the betterment of the same. Although students who did not fall within the targeted audience also took up the survey, their responses were analysed separately, but are not tabulated.

A survey in the form of a questionnaire was the preferred instrument of data gathering, as it is an easy tool to gather data about the collective preferences of large audience, when a number of variables are involved. Comparing the results and conducting an exhaustive analysis of the students' perspective of the engineering programme, and thereby determining the necessary parallels in which teaching and learning innovation are to be introduced are the central elements of the method.

The responses were tabulated and relevant graphs were plotted to help draw conclusions. Percentage distribution of the responses is a clear indicator of the preferences of the students.

Statistical evidence gathered from the analysis of the responses is a trustworthy indicator of the voice of the students in the shaping the trajectory of engineering education. The results are based on the assumption that the responses of the students are honest and legit.

3. Results and Discussions

1) Experiments: When asked if the experiments they performed in laboratories aided their understanding of concepts, 69% (226/328) of the students said 'Yes', while 28% (91/328) said 'Yes, but only with the use of state of the art equipment.' But when asked if these experiments stir their scientific temperament, the opinions were divided. 26% (87/329) said 'Yes', 35% (114/329) said 'Sometimes Yes'.

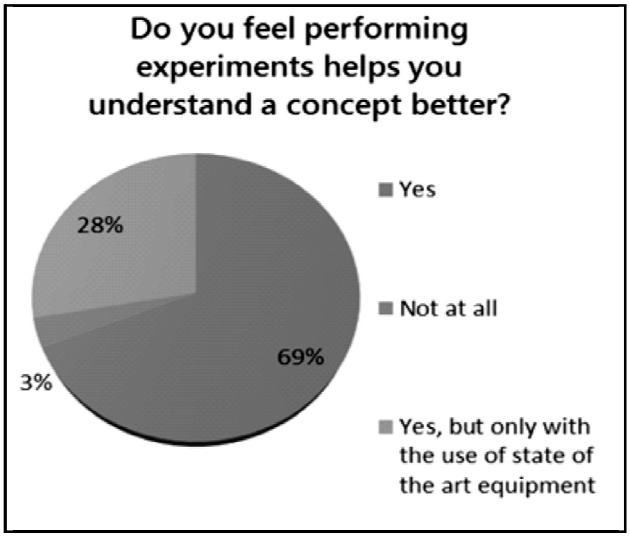

Figure 1

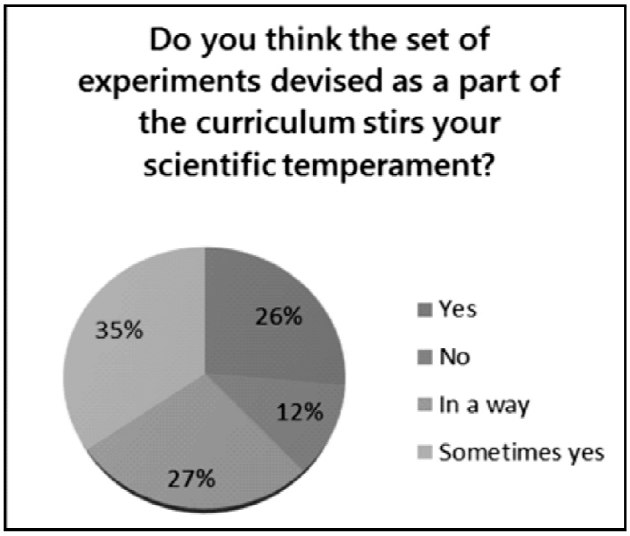

Figure 1

From the above, it can be stated that a majority of the students do feel that performing experiments is important, but they are unsure about it stirring their scientfic temperament.

Experiments are an indispensible part of any scientific endeavour. In this regard, the view of the student community is that state of the art equipment is necessary.

2) Student Bodies: While 92% (303/330) responded favorably when the importance of student bodies (technical clubs/societies) dedicated to subjects taught in class was questioned, 37% (121/330) said the main reason for joining such clubs was out of interest; 24% (79/330) and 20% (66/330) of the students opined that it was for 'Certificate' and 'Placement' respectively. The subjects took a neutral stand (142/330) when asked about the proactive involvement of students in such clubs, while a considerable population also took an affirmative stand (113/330).

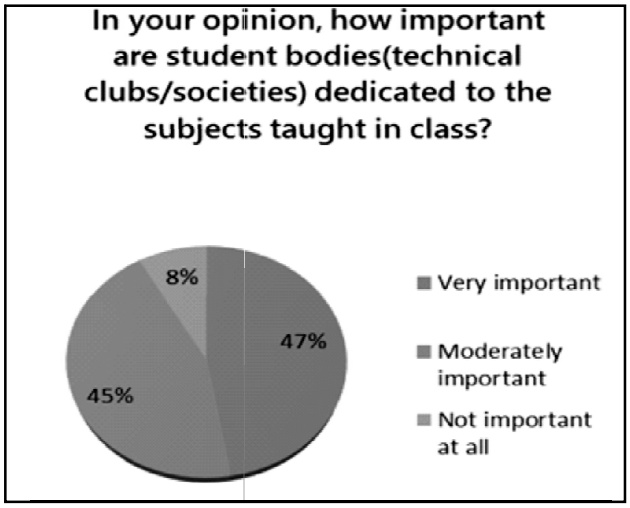

Figure 3

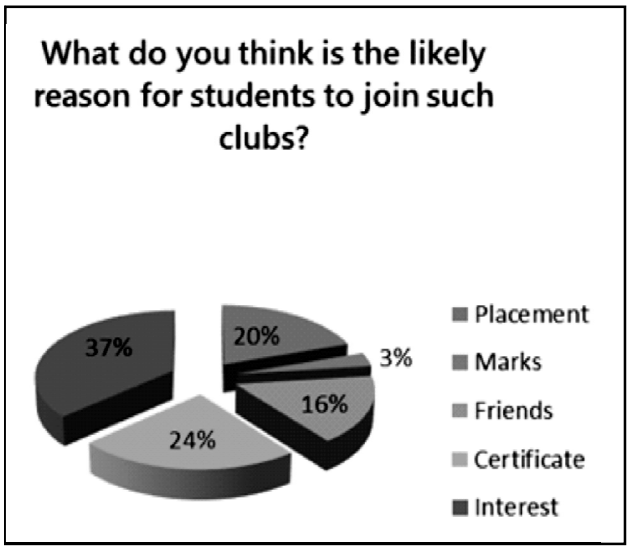

Figure 4

The need for student bodies has been unequivocally expressed by the students. While certificates, placements etc. lure them into joning such bodies occasionally, the enrolment is mostly because of interest.

3) External Source for Learning: Close to 80% of the survey-takers (264/331) agreed that the Internet is the best external source of information. About 42% (140/331) of them took courses or watched lecture sessions on online learning platforms only when

suggested by the faculty. A similar trend was observed when the students were questioned about suggested reading being a part of the curriculum - while a majority of them took a positive stand, a greater number were unwilling to do a suggested reading that wasn't graded by the faculty.

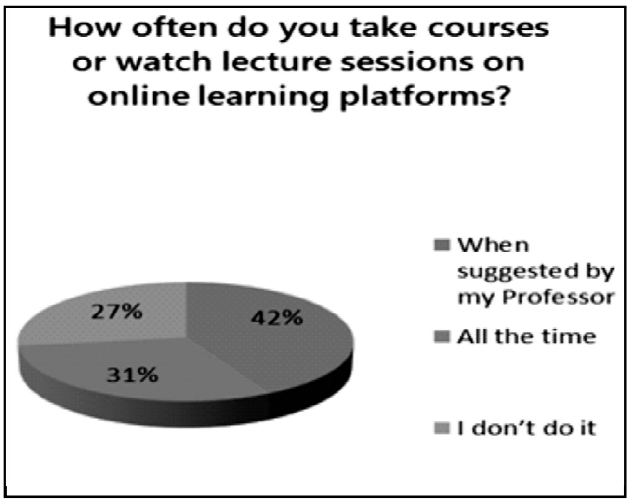

Figure 5

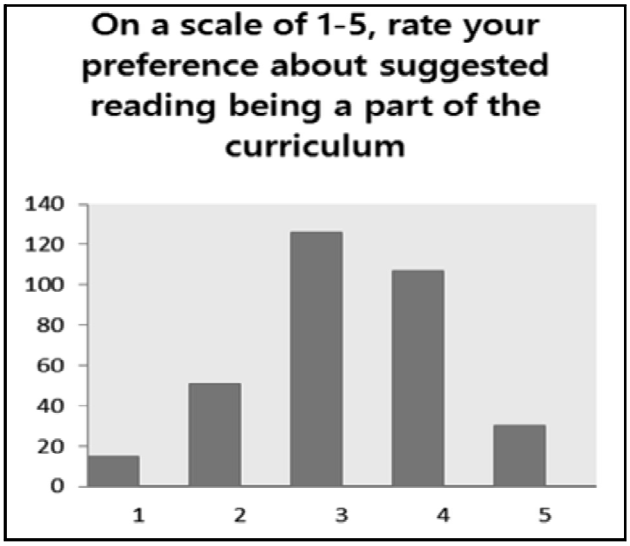

Figure 6

From the responses, it can be inferred that internet is the preferred tool for external learning. Taking up courses related to academics, on the internet, is favourved by the students. This is further catalysed if the course is recommended by a professor. The students, however, are slow on the uptake when it comes to doing a suggested reading which is not graded.

Exposure to qulaity resources is essential. Keeping in mind today's world-view, the internet goes a long way as a helpful tool in this regard.

4) Pure Science Subjects in Engineering: When asked about the importance of the inclusion of pure science subjects in engineering education, 92% (309/330) of the students responded positively, despite distributed opinions on how these courses should be included being recorded. A quarter of them preferred these subjects as a certification course; one third as a core subject and the rest, as an elective. Divided views were reflected in the responses when questioned about the position (academic year) of these courses being offered.

Table 1

Only in the first year	121	36.8%
In all four years	102	31%
When requested by the students	106	32.2%

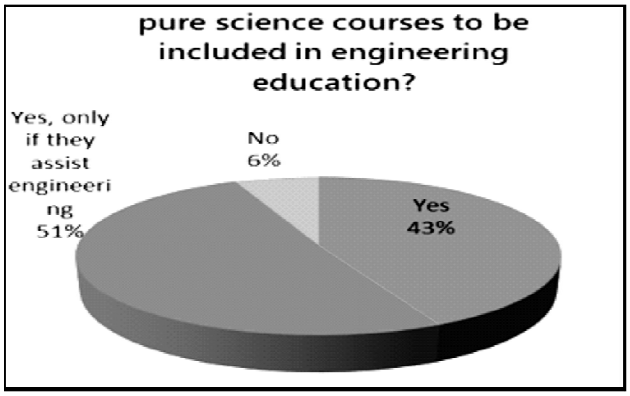

Figure 7

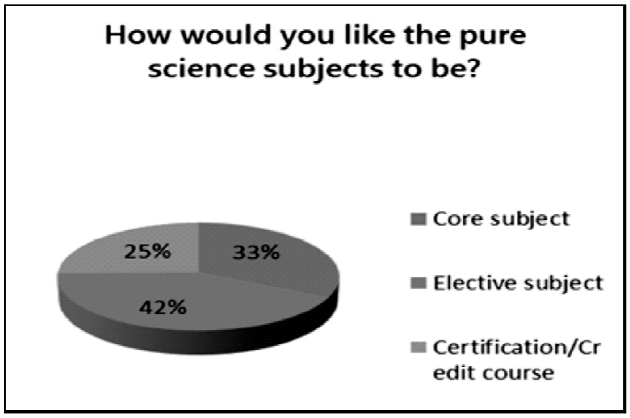

Figure 8

From the aforementioned, we can say that the students are positive about the inclusion of pure science subjects in engineering. However, consensus

is not reached on the nature of offering (elective, certification course etc.) of such subjects and the academic year(s) when they should be offered.

This section helps to further drive home the fact that science is an integral part of engineering activities.

5) Undergraduate Degree Comprising of Science and Engineering: While three-tenths of the students remained neutral when asked about a combined undergraduate degree comprising of both science and engineering, over 60% favored such a course. 36% of the subjects opined that such a course should span over a period of 4 years; while an equal percentage felt the duration should be 'Should be flexible.' At the same time, 19% and 9% of the students preferred a '3 year' and '5 year' course respectively. A programme of such a kind should primarily focus on 'skill development', 'research' and 'industry readiness' as the responses suggest. 80% (261/325) of the students expressed a desire to see 'All Engineering institutions' offer such programmes

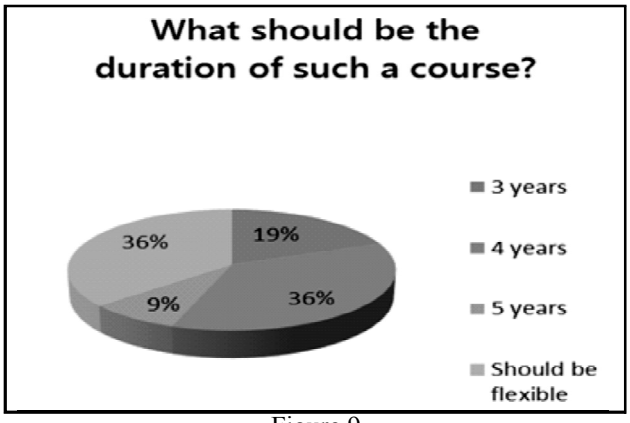

Figure 9

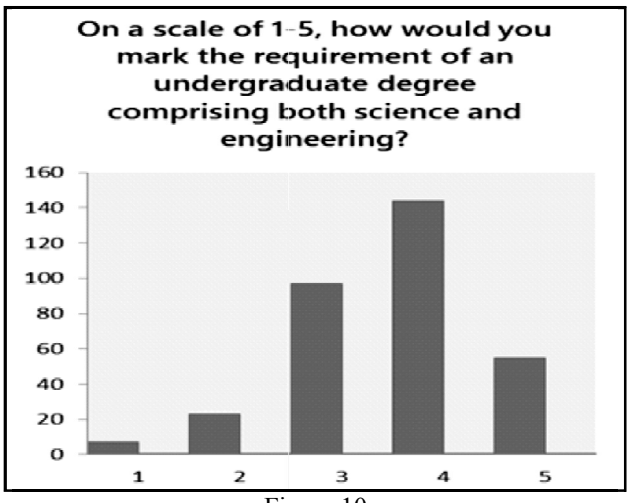

Figure 10

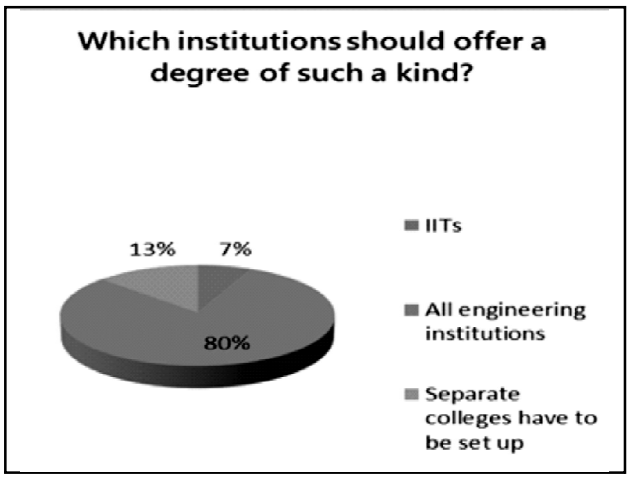

Figure 12

The evidence from these responses suggest a strong preference for a combined science and engineering course with prime focus on research and skill development. The need for all engineering institutions to offer such a programme is a collective consensus amongst the survey-takers.

There is a growing demand to address these requirements and make the students better equipped to solve the scientific and engineering challenges of the future.

4. Conclusion: With the vision of formulating a degree comprising of science and engineering, which is accessible by all undergraduate students, certain important verticals of engineering education – experimentation, student bodies, and suggested reading – were questioned in the survey.

The responses obtained, as provided before, are analysed here – by taking into account their interrelations.

Experiments, an integral part of scientific activities, should focus on kindling the inquisitiveness of the students. In the era of information bombardment, the internet is the primary source of acquiring scientific knowhow. However, it does not negate the vitality of experimentation.

Technical clubs are a platform for multidisciplinary collaboration. They help to keep the students abreast of the happenings in science and technology, and serve as a common ground to discuss, debate, and organise programmes that serve the collective interests of the student fraternity.

While suggested readings are considered important by the students, they are most effective when duly acknowledged by the faculty. Supplementing this, courses on online learning platforms are to be recommended and guided by the faculty.

Pure science subjects which are directly related to a particular branch of engineering (like, say, Chemical Engineering), are to be included as core-subjects in that branch. Advanced subjects that supplement learning can be suitably offered as electives or certification courses.

In the foregoing analysis, all the criteria considered, cater to the integrated undergraduate degree, which has to be offered by all engineering institutions. Having flexible (or four years) duration, such a degree has to focus majorly on research in science and technology and skill development - thereby making the students industry-ready.

The institutions which offer such a degree have to be equipped with the adequate level of infrastructure and resources that are demanded by the course.

Students holding a degree in pure science can be enrolled into the integrated degree program by means of a 'lateral entry'. This would allow them to join the course in the second or third year. The bachelors' degree conferred on them is to be different from those offered to the rest of the students, accounting for their qualification in pure science.

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