Assessing Curriculum Agility in a CDIO Engineering Education

ASSESSING CURRICULUM AGILITY IN A CDIO ENGINEERING EDUCATION

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ABSTRACT

Change and individualization are two aspects that are important in innovative higher education. In this paper, we argue for how the concept of curriculum agility can be used as a framework for engineering education that is able to meet societal, environmental, and technological challenges. In order to both anticipate and meet the needs of the rapidly changing world, engineering education needs to have an organization that allows for innovation, change and adaptation, with the capacity to respond within a (much) shorter timeframe than traditionally seen in higher education. The structure and processes of such organizations should include the time needed to establish and decommission new educational programmes, and the flexibility within the programmes. The CDIO's Curriculum Agility Working Group has defined seven principles for curriculum agility and has analysed how these relate to the CDIO Standards. This paper describes how the principles can provide guidance on both a curricular and institutional level. The principles are mapped against the CDIO Standards, relating to what is required for an agile curriculum, in order to indicate how the Standards can be utilized to assess the flexibility and agility of educational programmes.

KEYWORDS

Curriculum Agility, Stakeholder Involvement, Change Management, Self-Assessment, Standards: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

THE NEED FOR AN AGILE CURRICULUM

Engineering education is constantly exposed to change. Global changes, whether environmental, societal or technological, prompt internationally supplemented actions and responses. Other changes may be more local and context specific. Regardless of scope, these changes demand informed, well-designed, adequate, and timely responses. Therefore, it is essential that Higher Education Institutions (HEIs) are able to provide education that helps global citizens to conceive, design, implement and operate solutions or actions that address current and future changes and challenges, globally and locally (Crawley et al., 2014).

Today, STEM-universities are generally very good at undertaking research that is both topical and a driver for change in itself. Many research projects are initiated by current societal challenges, and the research strategies at the universities are directed to new needs and opportunities. In addition, an increasing number of innovations, both social and technological, have been quickly changing the conditions for companies as well as for communities. As HEI students will face many new challenges and changes that have not been seen earlier, a matching responsiveness is needed of HEIs, which will have an effect on their formats.

Flexibility and agility have been described and seen as necessary aspects in modern education. However, there seems to be no consensus on what curriculum flexibility and agility entail (Tucker & Morris, 2011). The term 'curriculum' in this paper is understood as comprising vision and rationale, aims and objectives, content, learning activities, teacher role, materials and resources, group learning, location, learning time, and assessment (van den Akker, McKenney, Nieveen, & Gravemeijer, 2006). The most common application of the concept is that curriculum flexibility is focused on adapting to, and facilitating for, the changing needs of the students. It is primarily a way of addressing and responding to different student groups (e.g. non-traditional students) by increasing accessibility to higher education (see Jonker, März, & Voogt, 2020) by means of addressing different factors such as, for instance, learning time, environment and preferences.

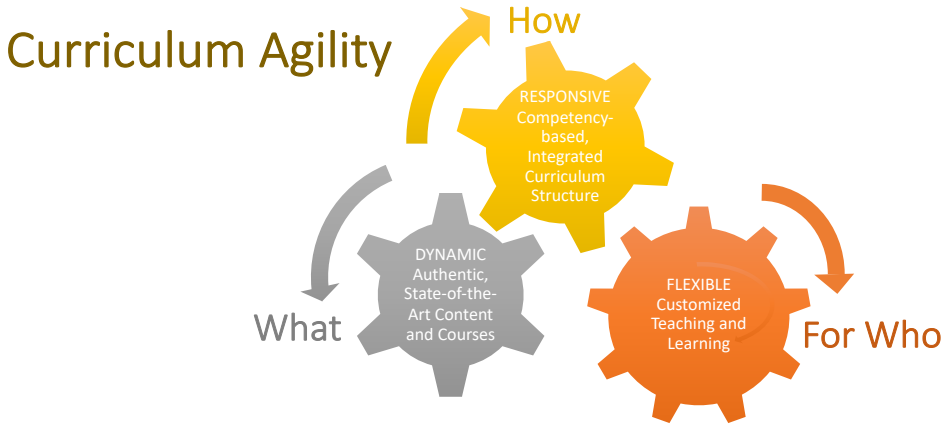

Figure 1: Curriculum Agility and its three controls (Brink, Admiraal, de Hei & Sjoer, 2020)

The overarching concept of curriculum agility described in this paper focuses on how higher education is able to (re)act to the rapidly changing needs that affect all aspects of the organization and processes of a higher education institution. Therefore, our definition of curriculum agility goes beyond flexible education and has a focus on adapting and adjusting to change from a holistic perspective. It consists of an educational structure organized to be

sufficiently responsive, allowing educational content to be dynamic where needed, and offering this in a customized, flexible approach to the increasing diversity of students and their individual needs, see fig 1.

Many engineering programmes currently work actively on the responsiveness, dynamic content, and flexibility of their education (Brink et al., 2019). However, there are often different obstacles ranging from governing regulations, academic traditions and views on educational content, to general systemic inertia that hinders the necessary improvements. The CDIO initiative is an example of a framework that can help develop a curriculum and syllabus that adequately respond to the needs of society, thereby giving students the necessary graduate attributes to engage with future challenges.

This innovative work is illustrated in a case study of an Industrial Design Engineering curriculum that, based on the twelve Standards of CDIO, worked towards agility. In five Standards (2, 5, 8, 11, 12) they made implicit openings for agility more explicit, such as co-creation, intercultural competences, international multidisciplinary projects, and integrated assessment for learning (Hallenga-Brink & Sjoer, 2018). This case also showed the need for an institutional organization that truly allows for innovation and adaptation.The organization should have the capacity to respond to new needs within a (much) shorter timeframe than traditionally occurs, including the time needed for establishing new programmes as well as decommininging existing ones, including the the dynamics and flexibility within programmes.

PRINCIPLES FOR CURRICULUM AGILITY

Our vision for the concept of curriculum agility — following the reasoning by Snow Andrade (2018) — is that we want *to ensure education that not only meets, but also anticipates, the needs of a rapidly changing world.* This vision has been iteratively processed within the CDIO community, starting with a workshop on curriculum agility at the 14th International CDIO Conference in Kanazawa, Japan, followed by further development at the EU and UK-NI Regional meeting in La Rochelle, France in 2018. The work was then continued as a Working Group during the 15th International CDIO Conference in Aarhus, Denmark, where the concept was further elaborated. Initially, ten principles for curriculum agility were established. After Aarhus, the working group continued the work and agreed on seven principles.

The seven principles were defined in order to develop a tool for assessing curriculum agility. This paper intends to describe how agility can be determined at a curricular and institutional level and how curriculum agility is reflected in the CDIO Standards. The principles, which can be seen in table 1, have therefore been compared with the descriptions and assessment criteria for the 12 CDIO Standards (CDIO Standard 2.1) in order to decide if, how, and at what levels the standards address curriculum agility.

Table 1. The seven principles for curriculum agility

Principle	
Stakeholder Involvement	Structures and procedures at the institution for identifying and prioritizing new needs, inviting stakeholder involvement in change processes to ensure an effective process for carrying out changes.
Organization and Governance	Ensuring an organizational structure that can effectively address the administrative system and institutional and national regulations in order to implement and maintain curriculum changes.
Decision Making	Having an effective curriculum and course approval process: timeframes, steps required, number of persons involved, communication channels.
Entrepreneurial Management	Establishing and maintaining a *change culture*. Ensuring a culture rather than a "one-person engagement". Establishing how change can be achieved initiative-driven: proactive rather than reactive.
Programme and Course Design	Allowing flexibility in programme and course design: adjustable projects, designing learning outcomes for change and flexibility. Also providing opportunities for students to build their own profiles.
Educational Innovation	Encouraging initiatives and innovation that promote education that is responsive and adaptive to change.
Pedagogy and Didactics	Promoting scholarship of teaching and learning among both teachers and students. Encouraging collegial teaching teams.

In the section below, the principles are clarified by exemplifying how they can be interpreted and used as rubrics from an institutional perspective.

Stakeholder Involvement is important in order to make sure input from different external and internal actors is collected, applied, and used to improve the results of the education and its organization. Stakeholders in STEM-education include (but are not limited to) representatives from industry and non-governmental organizations; government and communities; students; teachers. It is necessary for an HEI to have structures and procedures that allow for the exchange of ideas and input on requirements for education regarding different changes and needs. This principle also stresses active stakeholder participation in the co-creation of the education and throughout its change processes. The principle focuses on how and by whom changes in the curriculum are done.

Organization and Governance is the principle that deals with how an HEI is organized and what (overarching) structures and procedures govern its operations and activities at a programme and curriculum level. The organization of the institution needs to be such that the curricula can be responsive to (rapid) changes in their domain. This means that the systems and process flows must give room for customization, interdepartmental collaborations, informed, and well argued for, adjustments of university rules and departmental agreements. It also entails systematic facilitation of, and support for, successfully implementing the needed changes, both internally and externally, e.g. by professionalization, training and guidance.

Decision Making is about the process that a programme uses for changes to the curriculum, comprising both steps and timeframes. An effective decision-making procedure for curriculum development is also evaluated regarding the roles involved (including chain of command), and how the processes and decisions are communicated for impact in the organization. The principle covers starting new programmes or courses, making changes in existing programmes and courses, and decommissioning programmes and courses. The decision-making principle is closely connected to the principle Organization and Governance.

Entrepreneurial Management can be described as a principle for establishing and maintaining an approach to change as a natural and continuous part of curriculum design among the leadership of the institution. It is a principle that encourages and facilitates entrepreneurial thinking for curriculum development. It promotes willingness to act on new and

changing needs in society, and secures it in the organization. The willingness to change should not be dependent on individuals as single drivers for change.

Programme and Course Design deals with how the curriculum and courses are designed and developed and how flexibility can be addressed in existing and new programmes and courses. As a principle, it is intended to highlight the need for designs that allow for changes and adjustments to current needs. The principle also looks both at dynamic content as well as individual flexibility, permitting students to take ownership of their learning, for instance through course choices and alternative programme paths. The principle requires an institutional change promoting mindset and is linked to the principle Entrepreneurial Management.

Educational Innovation promotes change at an innovation level. This means that the institution's organization and leadership allow and encourage new initiatives, connections and experimentation in educational changes, regarding both content as well as teaching and learning. The principle is connected to Entrepreneurial Management, focusing on didactics. The innovations can vary from incremental to disruptive, yet always helping education to become more agile by improving the responsiveness of the system, the dynamics of the content, and the customization of the students' learning.

Pedagogy and Didactics stresses the importance for of teachers making informed choices regarding suitable pedagogical and didactic approaches and methods for flexible education. Scholarship of teaching and learning (SoTL) encourages teaching staff to apply the newest insights and contribute to finetuning established teaching methods to flexible, inclusive education for a diverse and fast changing student body. Collaboration in teaching teams is also encouraged as a means for educational development at the institutional level. Establishing and maintaining solid grounding via learning communities supports educational innovations and ensures the sustainability of programme and course design changes.

CURRICULUM AGILITY IN THE CDIO STANDARDS

In order to investigate how and to what extent the CDIO Standards meet the descriptions of the seven principles, the standards and principles were mapped against each other by participants of the curriculum agility workgroup. By comparing the description, rationale and rubric for each Standard with each agility principle, an overview of the matching could be made (see table 2).

At an overarching level, it became clear that the CDIO Standards allow (and to a certain extent stimulate) educational flexibility. It also became evident that the principles for curriculum agility require high scores in the self-evaluation rubrics for the standards. Even though curriculum agility is applicable to all standards from a holistic point of view, table 2 shows that several of the principles address curriculum aspects at another level than the standards do and are therefore not expressed in the standards.

Table 2. Mapping of the principles for curriculum agility against the CDIO Standards 2.1

Principles	Standard 1: The Context	Standard 2: Learning Outcomes	Standard 3: Integrated Curriculum	Standard 4: Introduction to Engineering	Standard 5: Design-Implement Experiences	Standard 6: Engineering Workspaces	Standard 7: Integrated Learning Experiences	Standard 8: Active Learning	Standard 9: Enhancement of Faculty Competence	Standard 10: Enhancement of Faculty Teaching Competence	Standard 11: Learning Assessment	Standard 12: Program Evaluation
Stakeholder involvement	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	N/A	N/A	Implicit	Implicit	Implicit
Organization and governance	N/A	Implicit	Implicit	N/A	N/A	Implicit	N/A	N/A	N/A	Implicit	Implicit	Implicit
Decision making	Implicit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Implicit
Entrepreneurial management	Explicit	Implicit	N/A	N/A	N/A	Implicit	N/A	N/A	Explicit	N/A	N/A	Explicit
Programme and course design	N/A	Explicit	Explicit	N/A	Implicit	Implicit	Explicit	Implicit	N/A	N/A	Implicit	Explicit
Educational innovation	Explicit	N/A	N/A	N/A	N/A	Explicit	N/A	N/A	Explicit	Explicit	Explicit	Implicit
Pedagogy and didactics	Implicit	Explicit	Explicit	N/A	Explicit	Explicit	Explicit	Explicit	Implicit	Explicit	Explicit	Implicit

In the following section the connection (or absence of connection) between the principles and the standards is described, including comments on how explicit or implicit the principles are addressed in the standards and to what extent the principles are relevant or not.

Principle: Stakeholder Involvement

The involvement of stakeholders is essential in engineering education. This is especially true for CDIO education which is manifested in the involvement of stakeholders' input in almost all CDIO Standards (except Standard 10, Enhancement of Faculty Teaching Competences). However, we argue that the standards can only be used in part to measure agility or flexibility of an educational program.

The Stakeholder Involvement principle focuses on the involvement in the change process to ensure effectivity, whereas the CDIO Standards are more focused on the involvement of stakeholders as informers to, or evaluators of, the education. As described in the standards, stakeholders ensure relevance and authenticity and provide feedback, reviews and recommendations on different aspects such as learning outcomes (2), integrated curriculum (3), introduction to engineering (4), design-implement exercises (5), workspaces (6), learning (7,8) and assessment (11).

In addition, it can be argued, at least to some extent, that Standard 12, Program evaluation, embraces the principle sufficiently well and that scale 4, "There is documented evidence that program evaluation methods are being used with key stakeholders including students, faculty, program leaders, alumni and working life representatives", is a good indicator for curriculum agility. However, it is not explicitly mentioned how stakeholders should be actively involved in the change process itself. It is therefore concluded that the standards involve aspects on means for exchange of ideas and input and processes for identifying and prioritizing needs for change but not how to include stakeholders in the actual change process.

Principle: Organization and Governance

The standards focus on the vision of education, the design elements of the curriculum, its contents, assessment system, and evaluation cycle, along with working spaces and staff training. The principle Organization and Governance is at another level of abstraction and therefore does not allow for literal placement within the standards. However, in some standards certain factors are important from the perspective of Organization and Governance for curriculum agility.

First of all, in order to allow curricula to be responsive to (rapid) changes in their domain, in Standard 12 it would be important to make the evaluation cycles short, well timed, and/or have an iterative character, as to make swift changes possible and not held back by the quality cycle tempo. It would also be important to open up for informed and argued adjustment of university rules and departmental agreements within the governance.

Secondly, to give room to customization and facilitate the innovation process by professionalization and training, it is important in Standard 10 to facilitate teachers' development of competencies in flexible education (within active and integrated learning) such as coaching, guidance, and reciprocal learning. These are not always part of the regular teaching professionalization programmes within HEIs.

Thirdly, stimulating interdepartmental collaborations will help both in Standard 2, to be able to teach the personal and interpersonal skills within multidisciplinary projects, and Standard 3, to make sure the walls between faculties and departments are prevented from forming barriers for integrated learning opportunities for students. Implicitly, these remarks fit within the standards' descriptions and rationales, but they are not explicitly mentioned and could thus be 'forgotten' in the self-assessment on the CDIO Standards, not leading to the desired curriculum agility.

However, two standards do give good guidance for the Organization and Governance principle of an agile curriculum. Within Standard 6 it is emphasized to facilitate agile, multipurpose, adaptable workspaces that can grow with the changes in industry as a HEI. And Standard 11 solicits an assessment policy that allows for integrated assessment on a integrated, dynamic body of knowledge and skills, something that is essential for curriculum agility to work.

Principle: Decision Making

There is little correspondence between this principle and the CDIO Standards. The principle focuses on structures and processes for decisions regarding curriculum development and other changes in the educational setting. The standards, on the other hand, are more focused on the aspects of teaching and learning in relation to the CDIO framework and ways of thinking about the necessary elements for an engineering education that follows the concept of conceiving, designing, implementing and operating. There is no description of by whom and how decisions should be made regarding changes in the educational offerings and the curriculum.

However, it could be argued that Standard 1 and Standard 12 meet some of the ideas of the principle, as scale 5 in the rubric mentions "continuous improvement" and "systematic and continuous improvement" in both standards. Nevertheless, there is no explicit mentioning of how this should be carried out. As is clear in the description of the principle, it is the actual procedural design that is in focus and how this allows for a responsive and timely decision-making *process*. The conclusion is that this principle and the standards are addressing different aspects and can therefore be seen as complementing each other without any evident overlap.

Principle: Entrepreneurial Management

At a first glance, one could perceive no association between the Entrepreneurial Management principle and the 12 CDIO Standards. To establish and maintain a proactive change culture in an organization is of fundamental importance when aiming to be agile. For this to work the

culture and the strategy and processes of the organization have to be aligned. The principle Entrepreneurial Management describes attitude and organization at a management level, the demand for a surrounding structure that drive change rather than simply responding to it.

As stated previously, the standards focus on how education should be led with all its elements, from curriculum design to assessment systems and evaluation cycles, including physical spaces and personnel. Curriculum change, however, does require continuous improvement, and for this to take place, we notice that at scale 5, in standards 1 and 12, there is a connection when continuous development is considered. We could also reason that Standard 2 is partly related to this principle as there should be responsiveness in the stakeholder's view of what outcomes are anticipated.

Furthermore, we may argue that for standards 6 and 9, there could be an implicit connection with the principle. For both the principle and the standards, it is anticipated that students become involved in the design process of workspaces. Similarly, a constant dialogue with faculty should be part of the process of setting necessary actions for their continuous development. As Blackmore and Kandiko (2012) suggest, the implementation of change requires considerable time spent in gaining support and planning.

Principle: Programme and Course Design

Fundamentally, the CDIO educational framework (Crawley et al., 2014) focuses on programme design to better prepare engineering graduates for employment. Therefore, this principle maps well with the standards and explicitly with Standards 2, 3, 7 and 12. There are implicit connections with Standards 3, 5, 6, 8 and 11, but no real ones with Standards 1, 4, 9 and 10.

The explicit links with Standards, 2, 3, 7 and 12 are due to these Standards dealing directly with the learning outcomes, subsequent integration of skills, and corresponding pedagogical approaches that affect curriculum design to optimize learning. It is suggested that Standards 2 and 7 would require a curriculum evaluation meeting scale 3 or better in their respective rubrics to ensure they could match the ideals of this principle, with Standards 3 and 12 requiring a score of 5 and 4 respectively.

The links with Standards 3, 5, 6, 8 and 11 are more tentative, mainly because their respective descriptions and rationales do not mention programme or course design specifically, but their content implies they would be important to ensure flexibility in any redesign process. It is suggested that their corresponding curriculum evaluation rubric scores should be scale 4 or better for Standards 5, 6 and 11, and 3 or better for Standard 8, to match the ideals of this principle.

Finally, it is worth noting that the successful implementation of Standards 3, 5, 7 and 11 might actually restrict opportunities for students to build their own profile by reducing course choice or alternative programme paths and hence oppose the ideals of this principle.

Principle: Educational Innovation

A clear correspondence of this principle is seen with the standards related to teaching (9, 10 and 11). We may say that it is imperative that bottom-up initiatives, such as faculty suggestions for changes, are supported. Innovative learning spaces require enhanced faculty competence. Therefore, it is equally important that teaching competence is developed and assessed. This principle could be checked against support structures at the institution (e.g. workshops, SoTL

conferences etc.). Considering that workspaces are naturally associated to teaching, Standard 6 also plays an important role as innovative education requires innovative workspaces.

When evaluating responsive education, reform initiatives not only apply to introducing CDIO but also adopting to changes in general. For this reason, the context of education (Standard 1) should consider fast changes to societal needs and demands. If educations do not respond quickly, they risk becoming hindrances to changes. For Standard 12, which suggests specific forms of stakeholder dialogues, evaluating the effect of changes towards agility could be relevant. In order to support education that is open and adaptive to change, constant responsiveness to demands and a need to build an institutional habit of change is necessary, as Clark (2003) states. Change needs to be institutionally sustained after transformation has taken place. Formal positioning and directorial influence are key points, otherwise initiatives will remain as marginal projects.

Principle: Pedagogy and Didactics

The principle can be described as the ability to make agility happen. In order to be able to respond to changing demands for engineering competencies, it is desirable that both curriculum design and the choice of pedagogies can be changed from one year to another. Several of the CDIO Standards are explicitly related to this. Standards 2 and 3 on Learning Outcomes and Curriculum design, which deal with design choices for the programme, and Standards 5-8, and Standard 11, which all deal with the implementation of the design choices, are clearly relevant. While scale 4-5 for these standards does not guarantee agility, it would be challenging to implement agility without high scores for these standards.

The Standard most relevant for the ability to do agility is arguably Standard 10 as it deals with the Enhancement of Faculty Teaching Competence. It is necessary that faculty staff have sufficient competence in order to be able to respond to pedagogically motivated design changes for the teaching-learning activities. Scale 4-5 is probably required for a continuously evolving agility to be possible.

The remaining standards are also of some relevance, at least implicitly, as all 12 Standards address different aspects of design and implementation of the curriculum. Standard 9 may be of interest if there are new technologies or theories that need to be introduced in the education, which may require that Faculty Staff learn about new content. Also, Standards 1 and 12 frame the standards and describe the processes where the need for new content and competencies may be identified. Standard 4, which deals with Introduction to Engineering, is likely to be the least important to address in terms of agility.

CONCLUSION

The idea behind the CDIO framework with its Standards and Syllabus is to provide a solid basis for a modern engineering education that is “constantly improved” (CDIO Vision). The purpose of the CDIO approach is to educate students who are “ready to engineer” (Crawley et al., 2014 p.11). This means that the students must be able to meet the changing demands of society and the work field and to develop products and tools that match the needs of today and tomorrow. Therefore, it is quite obvious that it is the intention of a CDIO-based education to be flexible and adaptable to societal, environmental, and technological changes.

When examining the Standards, it is also clear that the adaptation to change and the need for stakeholders' input to curriculum design and curriculum content are aspects that are emphasized in how the Standards have been formulated. In this paper, we have compared the Standards to seven principles for curriculum agility, and there is evidence that all Standards meet several of the principles. Curriculum agility can, therefore, be seen as part of all Standards and that this is explicitly expressed in the description, rationale or rubric of the individual Standards (except for Standard 4 that only implicitly corresponds to one of the principles).

Nevertheless, our discussions led to a consensus that there are aspects expressed in the principles for curriculum agility that are lacking in the Standards, and some of the principles are vaguely supported in the formulations of the Standards. A reason for this discrepancy is that some of the principles address issues at an institutional and organizational level that is beyond the scope of the Standards. It is also evident that there is divergence in focus in the Standards and in the principles. That is, the descriptors for curriculum agility naturally have a much higher resolution and a stronger focus in the principles. Consequently, it is clear that some of the principles and the Standards focus on different aspects and that they can be seen as complementary to each other rather than synonymous.

When it comes to assessing the agility of a programme or curriculum, it is clear that the Standards can give direction, especially when matching the highest score in the rubric of the Standard, but do not guarantee it. For a more thorough assessment, other, more precise, indicators need to be used. In the mapping process, some of the principles actually have proven to give direction to how to approach some of the Standards. The principles have been formulated in an attempt to look at curriculum agility from the different relevant educational and organizational levels. Several of these aspects cannot, and should not, be addressed in the CDIO Standards. Instead, some of the organizational aspects need to be understood and negotiated at a local or national level, depending on how the HEI is organized and governed.

The findings in this paper indicate the need for additional methods to assess curriculum agility as a complement to what is possible through the current CDIO Standards. For that reason, we propose continued work on the principles together with the development of a self-assessment tool that can be used by HEIs to evaluate their potential for designing curricula that meet current and future needs in an ever-changing world.

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BIOGRAPHICAL INFORMATION

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