Augmenting Formative Writing Assessment With Learning Analytics: A Design Abstraction Approach

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Abstract: There is increasing interest in use of learning analytics and technologies underpinned by artificial intelligence in the support of learning. In implementing and integrating these technologies there are challenges both with regard to developing the technologies themselves, and in aligning them with existing, or transformable, practices. In this paper we argue that by 'augmenting' formative tasks with learning analytics, we can achieve impact both through the integration of the tools, and through the support of existing good practices. We exemplify our approach through its application to the design of tasks for the key skill of learning how to write effectively. The development of these designs and their abstractions holds significant potential in bridging research and practice, by supporting the sharing and interrogation of designs in a way that is intimately tied to both practice (practical applied contexts), and research (through theorized and empirically supported designs targeting particular learning outcomes).

Keywords: writing analytics, learning analytics, learning design, conjecture maps, design patterns, technology enhanced assessment, technology enhanced learning, learning sciences

Introduction

Learning how to write analytically is a core skill in higher education and professional contexts (National Commission On Writing, 2003; OECD & Statistics Canada, 2000). However, its teaching is challenging, (Ganobcsik-Williams, 2006) with students often judging their work by more superficial criteria than the analytical standards that educators apply (Andrews, 2009; Lea & Street, 1998; Lillis & Turner, 2001; Norton, 1990). This may be considered a specific case of a common misalignment between people's perceptions of their own learning and reality (Bjork, Dunlosky, & Kornell, 2013). To address this misalignment, students should be inducted into academic practice to develop 'evaluative judgement', their ability to apply normative standards to assess the quality of work, in order that they are better able to self-assess their own work and thus to improve it (Boud, 2000).

To develop this evaluative judgement, there is a need to both implement tasks that target the learning of writing, and to research the learning of writing, in classroom contexts (Graham & Harris, 2014). In their 12 recommendations for designing high quality writing intervention research, Graham and Harris (ibid) note the importance of interventions that are "well-founded and designed", "representative of the real world context", and include "a series of studies to refine and test the writing intervention" (Graham & Harris, 2014, p. 96). Task designs, and the sharing of these, that support students in learning to write are important.

In this paper, we describe an approach to 'augment' learning designs for writing pedagogy, through the addition of automated writing feedback to writing tasks. As we describe in the following section, there is growing interest in the use of techniques drawn from the fields of learning analytics, educational data mining, or artificial intelligence as applied to education. The integration and implementation of these techniques to support learning in authentic contexts is an ongoing challenge. In the section 'Empirical Case Study' we describe a set of tasks that were designed specifically to develop student writing skills. These tasks are described through the lens of design abstractions that highlight the relationship between features of the design and the theorized pedagogic intent (described in 'A Design Based Approach'). By exemplifying this 'augmentation' technique, we highlight its potential to support communities such as AIED and ISLS to develop methods that support both research and implementation.

Writing analytics to support student writing

One means through which to support the learning of writing is through the provision of feedback to students that supports them in building their evaluative judgement – i.e., feedback that helps students learn to recognize what is good, and what needs improving, particularly in their own work. Such feedback might be provided through automated means, and indeed a body of work has investigated this potential in automated essay scoring (AES), which have been successfully deployed in summative assessment contexts (see, e.g., discussions throughout Shermis & Burstein, 2013). However, these AES systems are not without detractors (Ericsson & Haswell, 2006),

and much less attention has been given to the challenge of providing formative feedback, which to be actionable by the learner, requires more than the calculation of a grade. There is a growing recognition of the potential of computational approaches and natural language processing to be applied to formative feedback on student work, to support them in understanding where to improve, and develop their writing (see, for examples, Buckingham Shum et al., 2016; Knight, Allen, Gibson, McNamara, & Buckingham Shum, 2017; Passonneau, McNamara, Muresan, & Perin, 2017; Zhang, Hwa, Litman, & Hashemi, 2016).

However, the design and implementation of such systems should be conducted with regard to their potential as tools for intervention, and as Graham and Harris note, that has implications for design. Specifically, in developing learning analytics as a form of formative assessment (Knight, Buckingham Shum, & Littleton, 2014) on writing, they should be tested in real world contexts that provide for incremental improvement of the tool alongside impact on learning. To deploy such emerging technologies in formative contexts, we can conceive of two approaches. One approach would use technology to shift the focus of assessment to new kinds of process and product, for example towards choice based assessments (Schwartz & Arena, 2013) or 'performance assessment' (Linn, Baker, & Dunbar, 1991) that investigate the decisions students make in completing tasks. An alternative approach would investigate how existing systems might be 'augmented' by learning analytics, to provide novel feedback in existing high quality pedagogy (Knight, Forthcoming). While the potential of the former is transformative, its challenges include: the need to gather new data types, possibly using novel technology; and the expense and research required in order to develop new kinds of assessments. As Baker (2016) noted with regard to intelligent tutoring systems, adoption of artificial intelligence technologies has not been widespread, and thus our attention may be best focused on how to better use such intelligent systems *alongside* educators and students in flexible ways. Indeed, the need for pedagogically aligned learning analytics intervention designs has been highlighted as key in incorporating learning analytics within educational systems to improve existing teaching and learning practices (Wise, 2014). Given that for innovations to be taken up by educators, their distance from existing culture, practice, and technologies must be considered (Ferguson et al., 2014; Zhao, Pugh, Sheldon, & Byers, 2002), a focus on augmenting (rather than revolutionizing) existing practice may both support and enhance that practice, alongside raising awareness regarding – and implementation of – the role of these technologies for learning.

A design based approach

This paper, then, adopts a perspective of 'augmentation', by taking a design approach to analyzing teaching and learning contexts, to investigate where existing good practice might be augmented by learning analytics, further strengthening that practice. In our view, this approach is likely to increase adoption both of the analytics, and of the underlying practices, thus driving forward implementation of such learning designs, and the potential to research them. A similar call has been made in learning analytics applications for researchers to capture their pedagogical intents by aligning learning analytics to learning design. In this way, Learning Analytics can help to test the assumptions of learning designs by providing the necessary data, methodologies and tools to support the learning design in lieu of self-reported measures (Lockyer, Heathcote, & Dawson, 2013). In turn, knowledge of the pedagogical context that gives rise to the data is critical to its interpretation. The use of design abstractions can support this alignment, as we outline in this paper.

In taking a design approach, we specifically focus on a particular set of goal oriented design representations to support learning (Goodyear, 2005). Design abstractions that represent features of the design for learning thus aim to bring into alignment theory and practice to improve both (for example, Goodyear, de Laat, & Lally, 2006; Sandoval, 2014). These representations aim to share the general principles of a task design and purpose, specifics of a practical implementation, and design configurations targeted at particular outcomes. For example, 'design patterns' are abstractions that help in sharing existing practice in a way that supports its adoption across an array of learning tasks and contexts (Goodyear & Retalis, 2010). Good patterns foster research and adoption by: capturing existing practices that solve existing, complex, problems; abstract at the right level, neither too concrete or specific, or too general and divorced from context; gives insight into how it works, making clear why we should value it as a solution to the problem; links to other patterns in a structured way; and follows a generalized representation: a problem statement, the solution pattern, and a rationale for how the solution addresses the problem (Goodyear et al., 2006).

With a similar aim, conjecture mapping (Sandoval, 2014) involves understanding the ways that learning tasks make conjectures about how the learning should happen; these become testable, improvable, conjectures and designs (Sandoval, 2014).Tasks are thus analyzed for the *design* and *theoretical* conjectures they are based in. In common across conjecture mapping and design patterns is the desire to flag a key, high-level problem being addressed (a learning need). Across both, particular designs then embody or manifest the principles. Thus, a section of a pattern describes empirical background or evidence, and examples of the pattern's manifestations,

while conjecture maps describe a design's embodiment through tools and materials, task structure, participant structures, and discursive practices into mediating processes of observable interactions and participant artefacts; these mediating processes are then mapped to learning outcomes. *Design* conjectures thus describe assumptions about "how embodied elements of the design generate mediating processes," such that, "if learners engage in this activity (task + participant) structure with these tools, through this discursive practice, then this mediating process will emerge" (Sandoval, 2014, p. 22). *Theoretical* conjectures, then, describe "how those mediating processes produce desired outcomes"…in the form "if this mediating process occurs it will lead to…".

In the work described in this paper, we have undertaken a design process to:

1. Understand existing patterns of writing support in a particular institutional context, and develop abstractions of these
2. Augment these abstractions with additional – learning analytics based – abstractions (in this case, patterns) that complement the original designs
3. Evaluate the implementation of these patterns, to understand relations among them and the development of a larger pattern-set that can be augmented with learning analytics (that are described by patterns in their own right)

Empirical case study

In this section, we explain an empirical case study of our approach in the context of a design for writing instruction. The key components of the design are represented in a conjecture map shown in *Figure 1*. The specific sections of the task design which were augmented by analytics are displayed with a 'gear' icon. The elements of the design and the augmentation will be explained in detail below.

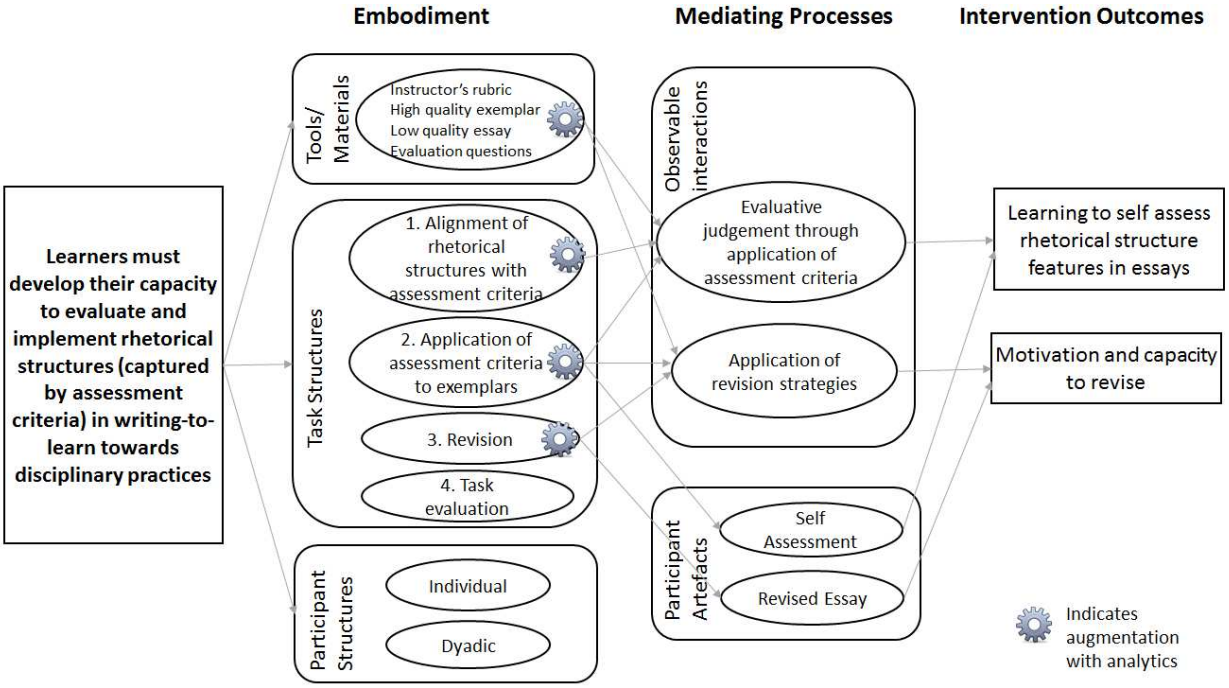

Figure 1. Conjecture map of a learning design for writing instruction, augmented by analytics.

The box on the left conveys the theoretically principled high-level conjecture, specifically, that in order to induct students into disciplinary practice, they must learn to write using the rhetorical structures that make up argumentative forms. This conjecture is then applied through its embodiment within a designed learning environment that uses three main elements: Tools/Materials, Task Structures and Participant Structures. The writing instruction is driven by the materials defined by the instructor (in tools/materials) and tasks described in the task structures, listed in the order that students complete them.

The current design was developed over three design iterations, described below. These iterations introduced changes around the use of analytics (tools/materials), and a dyadic task design (participant structures). Conjecture maps developed for each iteration can help in tracking the trajectory of the research by capturing the rationale behind the changes made to the design over the iterations. A key feature of the conjecture map is that it

separates the logic of the design from the specific instantiations, and provides a clear perspective on pedagogic sites at which learning analytics can *augment* the design towards the conjecture. In this case, a tool called AWA-Tutor (the Academic Writing Analytics Tutor) was developed that guided students through the tasks, and collected data for research, by integrating Writing Analytics in pedagogic contexts (Shibani, 2018; Shibani, Knight, Buckingham Shum, & Ryan, 2017). This tool provides an example case for the use of abstraction to develop research and implementation understanding of a learning context.

Writing analytics tools that make use of computational techniques produce feedback which is almost immediate. One such tool – "Academic Writing Analytics" (AWA) – uses natural language processing techniques, and has been embedded in an AWA-Tutor tool which allows students to submit their drafts and receive immediate feedback to make further revision in their texts. This enables students to assess their revisions based on the feedback and encourage further revisions upon assessment. This immediate feedback, made possible by analytics, can aid reflection and encourage improvement in student revisions on their drafts. While the current design is based on an automated tool which provides feedback on rhetorical structures in the text, the design can also be extended for tools that provide feedback on other text features.

Because the tasks were developed within an online tool, a separate evaluation question was also built into the structures, as indicated in the conjecture map. The artifacts highlighted in this conjecture map include specifically those artefacts about which learning conjectures were made. Since the artifacts from observable student interactions in the tasks could be useful proxies for students' learning, they are of interest to researchers and practitioners. Indeed, the artificial intelligence in education (AIED), learning analytics, and other communities have strong interest in analysis of such data. In the context of our design iterations, this interest is further developed in not only describing how conjectures may be made regarding the trace obtained through use of an online tool designed with pedagogic principles in mind, but also how learning analytics may *augment* these task designs. Here, we describe the final map with reference to its development, describing each design, and its analysis for research and implementation purposes. Drawing on (though not directly using) Alexandrian design pattern principles, here we highlight the core evolution of the tasks, in relation to the conjectures made, including through the use of computer aided augmentation.

DESIGN 1: Benchmarking and Automated Writing Analytics
Problem: We wanted students to engage with exemplars and their assessment, in order that they have an activity that (1) prompts them to critically apply the assessment criteria, (2) prompts them to engage actively with exemplars, (3) provides us as researchers with information regarding their ability to appropriately assess texts.
Task: The initial base task (task 2) consisted of a task in which students were provided with three exemplars of varying quality, and asked to assess those exemplars using the assessment criteria. The application of the assessment criteria involves a mediating process of evaluative judgement in the application of assessment criteria, which in turn should produce the outcome of improved self-assessment ability.
Tools/materials and participant structures: This task was designed for individual completion, making use of the instructor's rubric, and both high and low quality exemplars.
Iterations and Augmentation: The task design was modeled on an existing common practice at the institution. To augment this with writing feedback, in the initial iteration of the task, students were provided with texts that had been marked up using writing feedback (from either a tool for feedback on rhetorical structures in writing, or one focusing on spelling and grammar, or from the instructor). With the intent of foregrounding salient features of the texts through the provision of NLP-derived feedback in the form of

Analysis (unpublished) of this activity indicated that – as in previous iterations of the task design – the students appreciated access to the exemplars, and criteria. However, there were no clear differences between the ability of students to appropriately apply the criteria in the group with, or without, the automated feedback. In addition, the mode of interaction with both the exemplars (in the original task), and the automated feedback (in the 'augmented' version) is rather shallow. Thus, we sought to develop the task to provide opportunity for deeper interaction.

DESIGN 2: Benchmarking, Text-Revision, and Automated Writing Analytics
Problem: We wanted students to critically consider how specific features in the text instantiate responses to the assessment criteria, and to develop the student's interaction with the application of the criteria for building their understanding of how to – practically – improve a text.
Task: The initial task (task 2) was amended, and an additional task was added (task 1). Task 1 consisted of a task in which the students were asked to match excerpts from a text to the criteria that they addressed (for example, a sentence providing background information aligns with the criterion "Identification of relevant issues", while a sentence providing evaluation or analysis of a claim or piece of evidence aligns with the criterion "Critical analysis, evaluation, original insight". The revised task 2 involved students assessing a single exemplar text using the assessment criteria, and being specifically asked how they would suggest improving the text. In task 3, then, the students were asked to edit the text they were provided with (in an editable window, see *Figure 2*), and (task 4) to evaluate the improvements that they had made (i.e., to provide a new assessment of the quality of the text). Following task 4 the students were provided with their own text revisions, and those of an instructor on the same text, providing a 'good' exemplar to demonstrate the improvements made. While the original task (above) was intended to produce a mediating process of evaluative judgement, the revision task was – in addition – designed to produce a mediating process of revision strategy application, to produce the outcome of increased capacity and motivation to revise, and improved self-assessment ability. The first task was specifically designed to develop evaluative judgement through understanding of the assessment criteria, and thus to improve self-assessment through understanding of rhetorical structures.
Tools/materials and participant structures: As in design 1, this task was designed for individual completion, making use of the instructor's rubric, and in task 2 a lower quality exemplar, with task 4 providing the higher quality comparator. The instructor's rubric and the lower-quality exemplar drive the first and second-to-fourth tasks from the task structures list respectively.
Iterations and Augmentation: This task design developed from that described in design 1. As in that case, a between-subjects design was used to provide some students with instructor-based (static) feedback, others with dynamic feedback from AWA, and others with no feedback. Prior work has been conducted to establish conceptual relations between the instructor's criteria, rhetorical structures, and their specific instantiation in AWA (Knight, Buckingham Shum, Ryan, Sándor, & Wang, 2017). These relationships were foregrounded to the AWA group through static highlights flagging the AWA moves on the sentences to be aligned with the criteria. Then, the revision task was also augmented by AWA, with feedback provided on-request (via a button) to students as they revised the draft they were provided with.

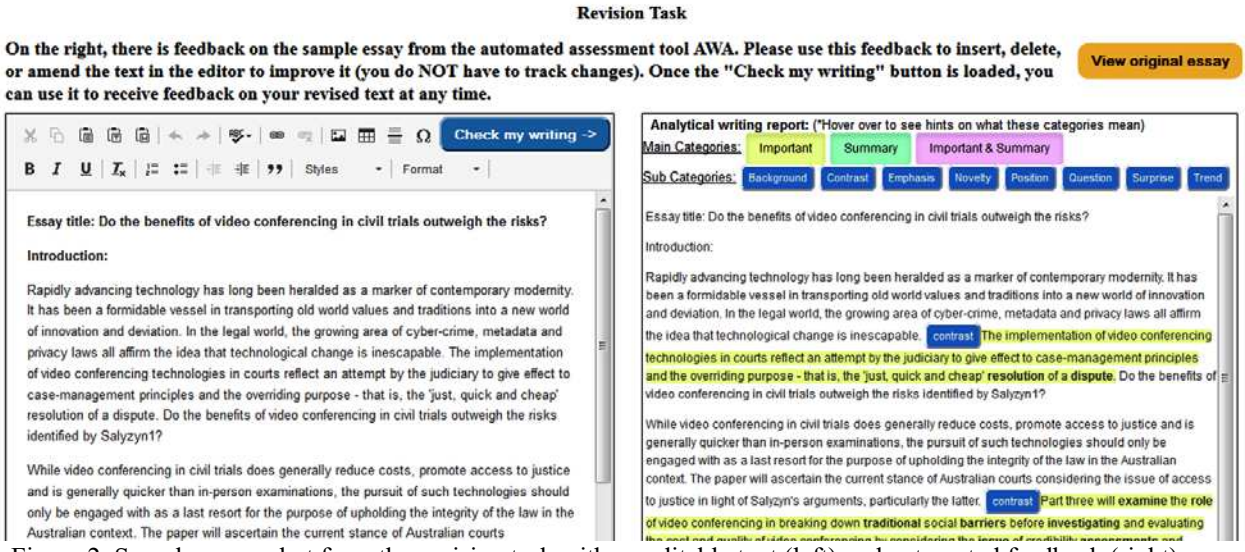

Figure 2. Sample screenshot from the revision task with an editable text (left) and automated feedback (right).

Analysis of this activity (preliminarily reported in, Shibani et al., 2017) indicated that across groups (with and without augmentation) the students generally found the tasks useful, and performed at equivalent levels when their text revisions were assessed. Feedback in places indicated that students would find it helpful to gain multiple perspectives on the texts and their revisions. Indeed, in conducting the work, it was observed that in some groups

students engaged in peer discussion as a part of the process. Moreover, prior research has indicated the benefits of peer discussion of assessment criteria and exemplars (Hendry, Armstrong, & Bromberger, 2012; Hendry & Jukic, 2014; Payne & Brown, 2011). Thus, peer discussion may provide a further mediating process. In addition, it provides a further site for possible augmentation (of the peer discussion), and – in contexts where feedback is provided on the exemplars and revisions – a site to investigate how that feedback is understood and discussed in application.

DESIGN 3: Benchmarking, Text-Revision, Peer-Discussion, and Automated Writing Analytics
Problem: Building on the previous designs, we additionally wanted students to engage with each other around the application of assessment criteria, to further develop their evaluative judgement, and ability to explain and justify their judgements of texts and their revisions.
Task: The initial base tasks in design 2 were adapted, such that in in one group of students they were asked to work as dyads, submitting a single revised text, and in the other group they worked individually.
Tools/materials and participant structures: In this design, the participant structure varied by group, with some working in pairs and others individually. When students work in dyads, they involve in discussion consisting of reflection and critique on the structure of essays and the application of automated feedback. The materials and tool for this design are the same as those in design 2.
Iterations and Augmentation: This task design developed from that described in design 2. A key concern in this design was that peer discussion may mediate the understanding and use of the augmented feedback provided by AWA; that is, this task may develop students' abilities to – critically – use such feedback, and that through observation of this dialogue research and implementation data is obtained. A further alternative design iteration (to be implemented in 2018) consists of asking students to work individually first (with, or without, augmentation), and then to work in dyads (or not) to create a hybrid revised text to submit.

Preliminary analysis of a pilot of this task indicated that across the paired vs individual and AWA vs instructor groups there were no differences in their reported 'usefulness' of the task, or quantity of revisions made (although no analysis of the quality of text revisions has yet been conducted). The instructor has reported a preference for peer discussion in the revision as an authentic practice. Further research is being developed to analyse both the outputs of the paired tasks, and the dialogue that students engage in and how it might mediate the automated feedback received (and vice-versa).

Conclusions and implications

Artificial intelligence and learning analytics hold unmet potential to address learning challenges. One means through which to increase their impact is through the *augmentation* of tasks grounded in practice, supported by research. Design abstractions, such as design patterns and conjecture maps, can support such augmentation. In this paper we have exemplified this approach by using abstractions to (1) understand the existing design of practices to support writing within a particular institutional context; (2) support the augmentation of these existing designs with additional – learning analytics based – design features that complement the original designs; (3) describe and develop the evaluation of the implementation of these patterns, in order to understand relations among the design features. In doing so, we indicate how larger task designs can be developed that augment formative tasks with learning analytics. This approach makes effective use of practitioner strategies for addressing pedagogic problems, thus grounding the use of learning analytics in tasks that are well established, and theoretically grounded. While this paper focuses on one example – writing instruction – the approach described has broad application. The approach described, then, addresses the general concern that innovation must address the needs of existing practice (Ferguson et al., 2014; Zhao et al., 2002), and the specific concern that writing interventions must be "well-founded and designed", "representative of the real world context", and include "a series of studies to refine and test the writing intervention" (Graham & Harris, 2014, p. 96).

By taking this approach, we intend to support existing good practice, develop implementation models for analytics, and provide opportunities for research that are grounded in practice and theory. The technologies developed for this particular task are used not only to engage students in those tasks, but also to gather data regarding student interaction with the tools, and provide opportunity for exploring how students engage with different kinds of (automated) feedback. By developing further design patterns, we can extend this work. For example, further patterns might augment the student text-revision with feedback on the revisions that they make, automate the allocation of peers based on ability or topical interest, or provide feedback to students on how well

they assess texts that they are provided with in the benchmarking. Each of these builds on a practice that can be described in terms of design patterns, each of which could be augmented with learning analytics designs.

In this paper, conjecture maps provide the 'argumentative grammar' that shows the broad design logic. However, these maps omit contextualized features of the designs across contexts, and detailed descriptions of task specifics and their relationships to design conjectures. Design patterns can address this concern by setting out in detail specific elements of a design, in such a way that the pattern may be adapted across contexts. By using these approaches we bridge the gap between research and practice, to represent and share designs in a way that is useful for both audiences.

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