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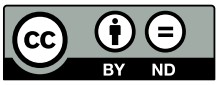

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Evaluating the Applicability of Alexander's Fundamental Properties to Non-Architecture Domains

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In his late work, the four-volume book The Nature of Order, Christopher Alexander introduces 15 fundamental properties that contribute to the "degree of life" a structure has. The concept of "degree of life", a concept Alexander introduces in that work, is a more specific, (at least theoretically) measurable indicator that refers to the wholeness of a form and whether it has the "Quality without a Name". In our research we are interested whether the 15 properties can be found in domains other than architecture. Alexander himself claims that the properties are universal and he shows many examples in nature, including forms of animals or cells that have these properties and that are alive and vivid. However, all of these examples draw from the physical and therefore geometric world. Do we find the same or similar properties in non-geometrical domains such as education, organizational structure, or software design? Moreover, can these properties really improve the quality – or in Alexander's words the "degree of life" – in existing forms?

Educational Patterns, Lecture Design, Degree of Life, Wholeness, Nature of Order

1. Introduction

The 15 fundamental properties are being increasingly found in domains other than architecture. In this paper we want to investigate the extent to which this mapping of the properties onto other domains actually works. Thus we will explicitly not reflect on the 15 properties in their application to architecture and geometric forms, but rather on their application to other domains and spaces (such as time-related or semantic spaces). Christopher Alexander himself (2002) indicated that the concept is applicable in other domains such as education. In order to find out whether the 15 properties actually work in other domains as well as in architecture, we developed a method to systematically search for the properties in existing forms of other domains. Instead of simply speculating about their meaning for other domains, the method fosters an open discussion by experts. Based on an analysis of design patterns of that domain, common properties are identified. By definition, design patterns should capture good and proven designs. Therefore, we can assume that we are likely to find most of the 15 fundamental properties in these patterns if they are actually necessary for vivid solutions in their respective domains. We do not assume that all of the properties are present in each pattern. However, we do assume that some of the properties are more often or are even always present and that there might be some (hierarchical) relations between them. We also differentiate between the structure that evolves during the application of a pattern (which especially in a non-physical domain might be volatile and short-living) and the resulting environment, which has been changed by this short-living structure. The potential properties found in these domains may be relevant for both the structure of the unfolding process and the structure of the resulting environment.

Our method evaluates the degree to which a given property is either directly present (without re-interpretation), indirectly present (mapping the meaning of the property onto the new domain with some re-interpretation), or absent in a given pattern. We also attend to the essential design goals or properties that are common in the specific domain. This enables us to find mappings from the 15 fundamental properties to their meaning in the given domain. If we cannot map all of the fundamental properties onto the specific properties of the domain, this could mean that the 15 fundamental properties are not all present for this domain. On the other hand, it could also mean that the domain has not yet defined all the properties that make designs more alive. To which extent the 15 fundamental properties can help to make better – more vivid, more alive - designs in other domains can be tested by (1) checking their presence in good solutions and (2) see how solutions can be improved by them.

In the following, we will provide a short overview of how other researchers have tried to

map the fundamental properties to new domains. Then we will describe our method in more detail. To exemplify our method and its result, we will apply it to five educational patterns about lecture design: SUITABLE CONTENT SELECTION, SUITABLE DELIVERY FORM SELECTION, REGULAR ATTENTION RECUPERATION, LECTURE STRUCTURING, and IMAGINATION STIMULATION (Köppe & Schalken-Pinkster, 2013). Finally we will discuss the results and the lessons learned.

2. The 15 properties and their abundant interpretations

There are a number of attempts to use the 15 fundamental properties in other domains. These include interpretations for software design (Coplien & Appleton, 1997; Coplien, 1998; Wirfs-Brock, 2008; Wirfs-Brock, 2010; Waguespack, 2010), computer mediated interaction (Schümmer, 2005; Schümmer & Lukosch, 2007), poetry (Gabriel, 2008) and education (Bauer & Baumgartner, 2011). There are also three works that discuss *The Nature of Order* and give summaries and cross-domain explanations of the fifteen properties: *Delight's Muse* (Quillien, 2008), *Mustertheorie* (Leitner, 2007) and *Thriving Systems Theory and Metaphor-Driven Modelling* (Waguespack, 2010).

The challenge is that the 15 properties express a high level of abstraction and do not directly translate to all domains. Thus many different interpretations of their meaning exist. In the domain of software development, Waguespack (2010, p. 12) maps the 15 properties of centers onto choice properties for system design: "to apply Alexander's concepts of physical structure to information systems, they must first be translated from a language of physical space to a language of cognitive space where physical positions and distance correspond to concepts and consonance in 'fields' populated by abstractions rather than shapes. The term choice serves well for that translation of Alexander's term center into this cognitive space." Some of his mappings are intuitively comprehensible, for example the mapping of Boundaries onto Encapsulation or of Good Shape onto Correctness. Other mappings are less comprehensible and are in conflict with other interpretations.

Let us consider two example properties: "Alternating Repetitions" and "Good shape" to get an idea how different the interpretations can be.

2.1. Alternating repetition

According to Alexander, "alternating repetition is the way in which centers are strengthened when they repeat, by the insertion of other centers between the repeating ones" (Al-

exander, 2002). In time, alternating repetition could be considered as rhythm: "Alternating Repetition comes into play when different phases in the group process require a different level of involvement. Group members will follow a rhythm of participation and passivity, which is then used to participate in other social contexts" (Schümmer & Lukosch, 2007). It is a sequence of centers that repeat but every repetition is adapted to its local surroundings: "strong centers repeated with alternating centers; not simple repeating: pattern with variation" (Gabriel, 2008b). In educational scenarios we find many alternating repetitions: a script or textbook has repeating elements (it is better structured if the same elements such as overview, discourse and summary are found again and again, alternating with the various topics); a rhythm of question and answer in lessons; presentation slides that separate topics and provide orientation are both boundaries and alternations to the content slides; the headlines in research papers alternate with the text. In programming, a loop with various parameters or a recursive call is an alternating repetition (Kohls, 2014).

2.2. Good shape

"Good shape is the way that the strength of a given center depends on its actual shape, and the way this effect requires that even the shape, its boundary, and the space around it are made up of strong centers" (Alexander, 2002). It seems that good shape is a rather complex quality of interacting centers that themselves together form a good shape, i.e. a strong form or a clear gestalt. This is similar to the law of Prägnanz in gestalt psychology (Quillien, 2008). There are different causes of Prägnanz. Something can be prägnant because it is the simplest interpretation of the perceived data; another cause is the familiarity with a form because known forms or categories can more intuitively be grasped. "Good shape" has an aesthetic meaning. It means that something is the way it should be. "Good" means to be a good exemplar of a category, an ideal in a Platonic view or a good schema in an Aristotalian sense. Gabriel (2008) calls something with "good shape" "a center that is beautiful in itself" so one can say that good shape means to be in a state of harmony and balance – to be beautiful. Coplien considers the idea of the good shape as an abstraction (Coplien & Appleton, 1997) or in terms of simple shapes "that are pleasing the eye (triangles, circles, stars, etc.)" (Coplien, 1998). This view is coherent with the law of Prägnanz.

However, complex shapes that are familiar can also become simple: familiarity with even a complex entity eventually makes it simple. In the field of software design, Wirfs-Brock (2010) considers a good shape to be "a shape that comprises recursive compact coherent centers, each exhibiting characteristic properties [such as] roles and patterns of collaboration, layers, sub-assemblies, modules, [and] domains". Waguespack (2010, p. 17) interprets good shape as overall correctness: "Good Shape brings us to the point of examining the

core of the concept, the essence of choices themselves. Together, the collective of choices constitutes the knowledge and understanding of the system under consideration. Relevant, complete, clear, and concise are the characteristics of choice quality, its Good Shape."

In pedagogy, a good method is one that satisfies its purpose and goals without violating the feelings of the students or teacher. A good "hands on practice" is one in which the student actually practices and has a positive and sustainable learning effect, e.g. the application of a math skill under supervision of a teacher or trainer. A bad shape of "hands on practice" is one that is too hard (students drop out), too simple (students get bored), without guidance (students get no feedback or help), or does not practice the skills that should be gained. Good shape means both a method or pattern that fits to the context (the intent) and its right implementation.

3. A method for mapping Alexander's fundamental properties

Our method consists of three iterative phases. The first phase consists of two steps and is performed by a group of researchers. First, their goal is to find general properties of the domain. Second, they work on a commonly agreed upon mapping from the 15 fundamental properties onto quality properties of a given domain. The second phase consists of three steps in which researchers independently evaluate patterns and check for the presence of the fundamental properties (first step), which additional properties exist (second step), and how the fundamental properties may improve existing patterns (third step). The third phase consolidates the evaluation of the independent reviewers.

3.1. Phase 1: General mapping of properties

In a first step, we list common properties of quality for the given domain, without having Alexander's 15 fundamental properties in mind. For example, in education we want to engage students, motivate them, help them reach their learning objectives etc. Other properties we might find include active or passive participation, positive relations between students, and moments of flow or enlightenment.

In a second step we try to find mappings from the 15 fundamental properties to the quality properties of the domain. We can either find a direct mapping, an indirect mapping or no mapping at all. A direct mapping is a straight-forward mapping that does not require any re-interpretation of the property. For example, alternating repetition is found many times in educational contexts: the repetition of lectures and pauses, the repetition of chapter

elements in textbooks (e.g. learning objectives – introduction – content – examples – exercises). Alternating repetition can also be found in social learning contexts, where groups constantly switch between forms of collaboration.

It is important that the similarity should not be on a superficial level but is coherent with Alexander's deeper meaning of the property. This requires referring Alexander's original texts to check whether the structural similarities are given. Focusing on the deeper meaning of a property can also help us to find a new interpretation of it for the domain. For example, "The Void" which is in Alexander's terms "the way that the intensity of every center depends on the existence of a still place – an empty center – somewhere in its field" (Alexander, 2002a) could be interpreted for the field of pedagogy to include methods for concentration such as letting one's mind wander, having time to relax, calming down in the classroom, and sinking into a book (Kohls, 2013). However, this is no longer a direct mapping but a re-interpretation that draws from the deeper meaning of the property. Obviously this can lead to some ambiguousness and in the long term we need an open discourse between experts whether it is an acceptable re-interpretation.

While the first two steps should be done in an open collaboration, involving the sharing of views and thoughts, the next three steps should be performed by at least 2 independent reviewers who evaluate patterns on their own. The main reason for using independent reviewers is to address ambiguousness. If independent reviewers come up with similar judgements it is more likely that there is substance to them.

3.2. Phase 2: Evaluating patterns for the 15 fundamental properties

The third step is to review more and more patterns of the domain and look for the presence of the 15 fundamental properties. The reviewer evaluates one pattern at a time and check for each fundamental property whether it is present in the pattern or not (or alternatively created/evolved by the pattern application). The reviewer decides whether s/he sees one of the fundamental properties directly in the pattern. A more challenging judgement is whether a property can be found indirectly. This is because one has to re-interpret the property for the domain. The common proposal of mappings (from step 2) can guide the reviewer. However, since the indirect mapping involves some ambiguousness, reviewers may find the presence of different properties based on their own interpretations. Therefore it is important that at least 2 independent reviewers tackle the same pattern. If 2 independent reviewers find the same properties or use the same re-interpretations it is more likely that the property is actually present in the pattern.

In the fourth step, reviewers write down which other properties, or domain specific values,

they can see in the pattern. For these properties they should briefly explain why they cannot be mapped onto any of the 15 fundamental properties.

In the fifth step, the reviewers consider the fundamental properties that are not present in the pattern. For each absent property they should briefly reflect in a thought experiment how the property could potentially improve the solution and write down their ideas.

3.3. Phase 3: Consolidation

The sixth and last step is to analyse the reviewers' independent evaluations and consolidate them. For each pattern the following attributes are identified:

- which properties have been found directly by one or more reviewers,
- which properties have been found indirectly by one or more reviewers with the same re-interpretation
- which properties have been found indirectly by one or more reviewers with different re-interpretation (indicating a certain level of arbitrariness),
- which additional properties have been identified by one or more reviewers,
- which potential ways exist to improve the solution by refining it towards the fundamental properties.

From the consolidation we can discern the extent to which the properties are actually present and how they help to form a better solution. As reviewers may come up with different re-interpretations, these can be included in the discourse about a meaningful mapping of the fundamental properties to the domain.

4. Applying the method to the domain of lecture design

To apply our proposed method we have chosen to focus on a specific field of higher education: the design of good lectures. Both authors have experience in delivering lectures, however, with a significant difference. Christian Köppe has delivered many lectures in a university context. The five foundational patterns for lecture design (Köppe & Schalken-Pinkster, 2013) are based on his experience and the experience of his colleagues as well as common literature. Christian Kohls has delivered many conference presentations and trainings. He now faces the task of designing new lectures as he recently became a professor. He can

use the five patterns as design guidance in planning his lectures. Hence, we have two perspectives on the same patterns: the perspective from the author/expert (who has already experience in designing lectures) and the perspective from the user/novice (who wants to use the expert's knowledge captured in the patterns to design a new lecture).

4.1. Quality Properties of lectures

Following the first step in phase 1, we tried to extract the most important qualities of good lectures. Given that lectures are ubiquitous in higher education one would expect that a clear and common understanding of these qualities can be found in the pedagogical literature. However, this is not the case. We reviewed several pedagogical guidelines found on the internet. The quality that "effective lecturers can communicate the intrinsic interest of a subject through their enthusiasm" can be found on learningspark.com but is not present in many other lists. Since e-learning offers many alternatives to traditional lectures, the authors believe that such social effects ("spark the enthusiasm") are likely to be more relevant in reference to traditional on-site lectures. We also found a good summary of positive functions of lectures on e-teaching.org, a portal to foster the use of digital media in higher education: teachers present state of the art and basic knowledge, lectures create the knowledge base for further activities (projects, practice), provide motivation for the domain, are a starting point for self-directed learning and give an overview over a whole topic/domain. Both authors of this paper also independently brainstormed what they expect from a "good" lecture. In an online discussion, we identified a list of important qualities of lectures. The list below summarizes the findings of the literature review and the brainstorming. It focuses on the most relevant properties (from the author's perspectives):

1. **Domain coverage**: Provides a good introduction and basic knowledge of a domain.
2. **Effectiveness**: Imparts knowledge and understanding.
3. **Motivation**: Catalyses motivation and interest in the domain.
4. **Inspiration**: Enables self-directed learning and further activities.
5. **Excitement**: Is exciting in a way that cannot be replaced by textbooks or films.
6. **Flow**: Does not overwhelm or bore, supported by a balanced level of challenge.
7. **Economy**: Makes use of the available time in the most efficient way.
8. **Engagement**: Promotes active involvement of students with the topic during the lecture.

4.2. Applying Phase 1: Mapping the 15 properties to educational properties

After we had agreed on these eight properties as a working list, we were able to reflect on potential mappings from these eight properties to Alexander's 15 fundamental properties. As a supporting step we first looked for occurrences of the 15 fundamental properties in lectures in general. Deriving from these examples, we found mappings to the educational properties.

We invite the reader to reflect upon whether s/he agrees with the mappings, which of the mappings are direct or indirect, and which other mappings come to mind. What we can see already is that there are several potential mappings for each of Alexander's 15 properties. This means that one Alexandrian property can support more than one educational property.

Levels of Scale can be mapped onto Domain Coverage by having smaller knowledge chunks that build on each other to cover a whole topic.

Levels of Scale can be mapped onto Flow (not overwhelming or boring students) by providing knowledge that fits and integrates into a bigger picture and dividing more difficult challenges into smaller and easier challenges ("divide and conquer").

Levels of Scale can be mapped onto Economic by efficiently providing knowledge and building/stabilizing the big pictures by smaller foundations.

Strong Centers can be mapped onto Domain Coverage, Effectiveness and Economic by providing a mixture of information, multiple views, being a whole and structured unit, and by bundling knowledge fragments instead of splitting apart what belongs together.

Strong Centers can be mapped onto Inspiration by building/connecting the content to other activities, or being the "glue", by bringing students together to connect and share experience, and by making announcements and tips available for all attendees.

Strong Centers can be mapped onto Economy by having a lecturer with experience who guides students effectively through the basics.

Boundaries can be mapped to Motivation by separating and connecting theory and examples to real-world problems.

Boundaries can be mapped to Engagement by providing social boundaries, (e.g. in which the professor and students physically face each other) and by avoiding distractions (i.e., pauses to separate lectures from previous thoughts or activities – pauses provide time to shift focus and attention).

Alternating Repetition can be mapped onto Domain Coverage by providing an optimal and reliable sequence of presentation styles, ensuring that important information (examples, teaching goals) is provided on a regular basis and ensures that students know what to expect.

Good Shape can be mapped onto all of the eight educational properties since a good shape – that is a good lecture – should show all of these qualities.

Local Symmetries can be mapped onto Domain Coverage and Effectiveness by presenting coherent content and adapting the content to an audience with similar skill level.

Local Symmetries can be mapped onto Motivation and Flow by being coherent and matching the expectation of students.

Local Symmetries can be mapped onto Excitement as student meet friends and can interact with them and with the lecturer.

Deep interlock and ambiguity can be mapped onto Motivation if the knowledge strongly relates to students expectations, their goals, problems and experience.

Deep interlock and ambiguity can be mapped onto Inspiration because "guidance" to self-directed activities is an ambiguity.

Contrast can be mapped onto Domain Coverage and Effectiveness by showing what is important and what is not, by understanding cause and effect, and by assuming that knowledge is indeed a differentiation of the world (as in ontologies).

Contrast can be mapped onto Excitement if the body language and excitement of teacher signals what is relevant for real life (or for exams), and by involving many more senses than books or video lectures.

Contrast can be mapped onto Economy by highlighting content, developing it step by step, and drawing conclusions.

Gradients can be mapped onto Domain Coverage and Effectiveness by having a well-shaped sequence that builds up the big picture step by step and avoiding unexpected changes of direction, and by making everything fit together and feel coherent.

Gradients can be mapped onto Motivation by not loosing students with too-difficult challenges at the beginning and increasing the level of difficulty stepwise, and by letting students experience progress and reach milestones.

Gradients can be mapped onto Flow by constantly adapting the level of difficulty, and increasing the level of challenges step by step.

Gradients can be mapped onto Economy by directly leading students down the path to the learning goal, from the unknown to the known.

Roughness can be mapped onto Motivation by changing the standard content and accounting for current affairs and problems, integrating the latest results of research, and allowing the lecturer to avoid becoming bored from having to present the same things again and again.

Roughness can be mapped onto Inspiration by providing spontaneous tips for further resources, leaving gaps to be filled in by students and by allowing students to explore their own solutions.

Roughness can be mapped onto Excitement by adapting to the current needs and skills of the audience, integrating surprises and providing space for anecdotes and jokes.

Roughness can be mapped onto Flow by making it possible to adapt the level of difficulty and constantly evaluating the reaction of students, and by allowing students to ask questions.

Roughness can be mapped onto Engagement by allowing interaction with students, connecting with students and not being serious all the time. Additionally, committing the occasional faux-pas makes a lecturer more natural.

Echoes can be mapped onto Effectiveness by learning through repetition and induction of mental schemas.

Echoes can be mapped onto Inspiration and can support self-directed learning if the content is echoed in scripts, text books, exercises and other resources.

Simplicity and Inner Calm can be mapped onto Doman Coverage and Effectiveness by making content more accessible, by making complexity easier to grasp, by dividing and conquering, chunking information, and by having coherent content that does not irritate.

Simplicity and Inner Calm can be mapped onto Motivation by not overwhelming students ("I can do this").

Simplicity and Inner Calm can be mapped onto Flow and Economy by making things simple without oversimplifying.

Simplicity and Inner Calm can be mapped onto Engagement because students can follow the content and contribute.

The Void can be mapped onto Inspiration by letting the mind wander, providing gaps that can be filled with life by students.

The Void can be mapped onto Inspiration by providing pauses for reflections and letting the content "sink" in.

Positive Space maps onto Domain Coverage as each text/content section gets its meaning from the surrounding content sections. The meaning of a phrase depends on its context.

Positive Space maps onto Motivation because in a learning community (students sitting together in the lecture hall) there are shared goals and social identity emerges; students define themselves in relation to other students who are present.

Positive Space maps onto Economy because learning materials should be accessible and designed for optimal perception.

Not-Separateness can be mapped onto Domain Coverage and Effectiveness by providing content that builds on and relates to other content.

Not-Separateness can be mapped onto Motivation by connecting content to the goals and interests of students, connecting content with other activities and real world problems, and providing meaning.

Not-Separateness can be mapped onto Inspiration by referring to other activities ("you will need this to solve the next programming exercise or understand this drama"), and by referring to further resources.

Not-Separateness can be mapped onto Excitement through social experiences and a stronger commitment of students who show up.

Not-Separateness can be mapped onto Economy by connecting to existing content (which is very effective), by building skills and providing information required for higher level activities, and by making the curriculum whole.

Not-Separateness can be mapped onto Engagement by socially involving students and connecting the content to the students' interests.

4.3. Applying Phase 2: Finding the properties in the patterns

The second phase of our method evaluates the 15 properties not with regard to lectures in general but rather with regard to lecture design patterns. Here we looked at the five patterns that are intended as a foundation for good lecture design (Köppe & Schalken-Pinkster, 2013). The findings for one of the patterns are described next.

The pattern "Suitable Content Selection" has the following properties (drawing from both the 15 fundamental properties and the eight educational ones). In what follows, "dm" stands for direct mapping, "im" for indirect mapping and "ep" for educational property .

Each author independently selected aspects of the pattern and mapped them onto the properties. Hence, two different aspects could lead to the same property. For example, author #1 indirectly mapped "Separate different content types" to Strong Centers, whereas author #2 mapped "Content best be presented by lecturer" directly to Strong Centers.

- Suitable Content Selection – Mappings of pattern aspects to properties by author #1:
- Separate different content types -> Strong Centers (im), Boundaries (im), and Contrast (dm);
- Identify content that is available in other resources -> Not-Separateness (dm) and Inspiration (ep);
- The checklists define what the conceptual difference between the content types is -> Contrast (dm);
- Provide the big picture in lectures -> Not-Separateness (dm);
- Examples in lectures -> Alternating Repetition (dm), Echoes (dm), and Local Symmetry (im);
- Link knowledge to existing knowledge -> Not-Separateness (dm);
- Reduce lecture content to those content types that require personal presentation -> Simplicity and Inner Calm (im) and Excitement (ep);
- Avoid being boring or overwhelming -> Good Shape (dm), Flow (ep), and Economy (ep);
- Adapt examples to audience -> Roughness (dm) and Motivation (ep);
- Put in larger context, i.e. implications for society, organizations -> Not-Separateness (dm) and Motivation (ep).

In addition, we can identify these positive properties: Take diversity into account, connect to larger context (societal), create value and meaning for students, provide only the essentials / starting points, feedback, interaction, provides the big picture.

Alexander's properties	Our educational properties	Additional educational properties
Levels of Scale	Provide basic knowledge	Take diversity into account
Strong centers	Gain knowledge and understanding	Connect to larger context (societal)
Boundaries	Motivation and interest for domain	Create value/meaning for students
Alternating repetition	Self-directed learning, further activities	Provide only the essentials / starting points
Positive space	Exciting event, no replacement possible	Feedback, interaction
Good shape	Flow experience	Big picture
Local symmetries	Effective, efficient	
Deep interlock and ambiguity	Active involvement of students	
Contrast		
Gradients		
Roughness		
Echoes		
The Void		
Simplicity and Inner Calm		
Not-separateness		

Table 1: Mappings of author #1

Suitable Content Selection – Mappings of pattern aspects to properties by author #2:

- Content best be presented by lecturer -> Strong Centers (dm) and Effectiveness (ep);
- Pointing to self-study content -> Boundaries (dm), Contrast (dm), Simplicity & Inner Calm (im), Not-Separateness (dm), Inspiration (ep), and Economy (ep);
- Covers interrelationships of elements -> Strong Centers (dm), Boundaries (dm), Contrast (dm), Not-Separateness (dm), Domain Coverage (ep), and Effectiveness (ep);
- Critical content parts -> Strong Centers (dm);
- General feedback on students' performance -> Inspiration (ep) and Effectiveness (ep)

- showing wider implications/perspective -> Not-Separateness (im), Motivation (ep), and Excitement (ep);
- Relevant examples -> Strong Centers (dm), Good Shape (im), Not-Separateness (im), Effectiveness (ep), and Motivation (ep);
- Linking old to new -> Alternating Repetition (dm), Not-Separateness (im), and Effectiveness (ep).

In addition, we can identify these positive properties: feedback as "confirmation" or for correction, linking new to big/surrounding (giving it a broader contextual meaning).

Alexander's properties	**Our educational properties**	**Additional educational properties**
Levels of Scale	Provide basic knowledge	Feedback as confirmation/ correction
Strong centers	Gain knowledge and understanding	Linking new to big/surrounding
Boundaries	Motivation and interest for domain	
Alternating repetition	Self-directed learning, further activities	
Positive space	Exciting event, no replacement possible	
Good shape	Flow experience	
Local symmetries	Effective, efficient	
Deep interlock and ambiguity	Active involvement of students	
Contrast		
Gradients		
Roughness		
Echoes		
The Void		
Simplicity and Inner Calm		
Not-separateness		

Table 2: Mappings of author #2

4.4. Applying Phase 3: Consolidation

It is important to remember that the analysis of the patterns was made independently by each of the authors. This is the reason why their mapping is based on different aspects of

the pattern's solution. In a third and final phase we consolidated the mappings. That is, if one of the authors found a property (e.g. Echoes) and the other did not, the consolidation still expressed that Echoes was found in the pattern. However, in the consolidation we also quantified how many times a property was identified and whether it was mapped directly or indirectly.

Alexander's properties	**Our educational properties**	**Additional educational properties**
Levels of Scale	Domain coverage: 1 mapping 1 mapping by author #2	Take diversity into account
Strong centers: 5 mappings *4 direct mappings by authors #2* *1 indirect mapping by author #1*	Effectiveness: 5 mappings 5 mappings by author #2	Connect to larger context (societal)
Boundaries: 3 mappings 2 direct mappings by author #2 1 indirect mapping by author #1	Motivation: 4 mappings 2 mappings by author #1 2 mappings by author #2	Create value/meaning for students
Alternating repetition: 2 mappings 1 direct mapping by author #1 1 direct mapping by author #2	Inspiration: 3 mappings 1 mapping by author #1 2 mappings by author #2	Provide only the essentials / starting points
Positive space	Excitement: 2 mappings 1 mapping by author #1 1 mapping by author #2	Feedback, interaction
Good shape: 2 mappings 1 direct mapping by author #1 1 indirect mapping by author #2	Flow experience: 1 mapping 1 mapping by author #1	Big picture
Local symmetries: 1 mapping 1 indirect mapping by author #1	Economic: 2 mappings 1 mapping by author #1 1 mapping by author #2	Feedback as confirmation/correction
Deep interlock and ambiguity	Engagement	Linking new to big/surrounding
Contrast: 4 mappings 2 direct mappings by author #1 2 direct mappings by author #2		
Gradients		
Roughness 1 mapping 1 direct mapping by author #1		
Echoes 1 mapping 1 direct mapping by author #1		
The Void		

Alexander's properties	Our educational properties	Additional educational properties
Simplicity and Inner Calm: 2 mappings 1 indirect mapping by author #1 1 indirect mapping by author #2		
Not-separateness: 9 mappings 4 direct mappings by author #1 2 direct mappings by author #2		

Table 3: Consolidation of both author's mappings

5. Conclusions

Our most obvious finding was that we found many of Alexander's 15 properties in the pattern – indeed more than we expected. In most cases a mapping onto the property was found by both authors. However, there were differences as to how many mappings they found and whether they directly or indirectly mapped onto the property. Almost all of the educational properties were found for the pattern by at least one author. There is no differentiation between direct and indirect mapping for education properties, since they are already rooted in the educational domain and require no re-interpretation. Both authors also identified additional educational properties for the pattern.

5.1. Reflections on the 15 fundamental properties applied for education

Another noteworthy result is that some of Alexander's properties show a more intense presence than others. We found several occurrences of strong centers, contrasts and not-separateness. While we selected only one pattern for illustration, the same can be found for the other patterns. Strong Centers, Echoes and Not-Separateness where indeed identified multiple times for each of the five patterns. We can also report that all of the 15 properties were identified in at least one pattern. Positive space and Simplicity & Inner Calm were only identified once. All the other properties were also identified several times but could not be found in all of the patterns. One of the reasons that Strong Centers, Echoes and Not-Separateness were found more frequently could be that for each of these properties we also found many different mappings to educational properties (see previous section).

As for the educational properties, we found that all of the properties were present in one pattern or another. However, none of the educational properties was present in all five patterns. This implies that the interplay of multiple patterns is required to achieve all of the educational properties (or values).

5.2. Reflections on the educational properties and their relation to other properties

In the process of analysing each of the patterns we also identified additional educational properties that were present in multiple patterns:

- **Diversity**: address different student skills, interests and learning styles
- **Contextualization**: connect to existing context, student's interests and societal contexts
- **Social Interaction**: provide feedback, adapt to the current situation and to social interaction
- **Orientation/Big picture**: orient students to, the big picture and understanding of the learning goals and help them relate the content to these goals
- **Curiosity**: surprise students, and foster exploration and experimentation

Diversity may be generated by Alternating Repetitions, Gradients, Contrast, Local Symmetries (instead of global ones) and Deep Interlock and Ambiguity. Contextualization may be generated by Levels of Scale, Gradients, and of course Not-Separateness. Social Interaction may be generated by Strong Centers, Boundaries, Positive Space, Echoes and Not-Separateness. Orientation and the Big Picture may be generated by Levels of Scale, Gradients, Good Shape, Simplicity & Inner Calm, and Not-Separateness. Curiosity may be generated by Roughness, The Void, and Deep Interlock and Ambiguity.

We have previously seen that one of Alexander's 15 properties can be mapped to multiple educational properties. We have also argued that the additional educational properties can be generated by several of Alexander's properties. This suggests that there is a many-to-many relation between Alexander's 15 properties and the educational properties rather than a 1:1 relationship. Also note that we have speculated that these properties can be "generated" by some of the fundamental properties. Alternatively we could say that some of Alexander's properties support a specific educational property. It is an open question as to whether the idea of "supporting" is also better than "mapping", i.e. a fundamental structural property rather supports an educational property than being mapped onto an equivalent. For example, Level of Scales supports Domain Coverage, Flow and Economy rather than saying that Level of Scales directly or indirectly maps onto Domain Coverage, Flow and Economy, assuming that this fundamental structural property and the mapped educational properties are the same.

5.3. Hierarchy of abstraction

Besides the many-to-many relationship (rather than a 1:1 relationship), we also found a different hierarchy of abstraction for the educational properties. Domain Coverage, Effectiveness, Motivation, Inspiration, Flow, Economy, Engagement, Diversity, Contextualization, Social Interaction, Orientation, and Curiosity do not always have a structural nature but are rather abstract values or achievements. As such, they are rather emergent qualities that are based on the 15 fundamental structural properties. They are on an intermediate level between the ultimate goal of wholeness and the fundamental structural properties. While they are more abstract (various fundamental structural properties can lead to the same educational values) they are also more specific because they provide meaning for a specific domain. We could say that we have a hierarchy of abstraction in which

1. **wholeness** is the ultimate goal,
2. the **interplay of educational properties** (values) makes education whole,
3. the **interplay of structural properties** supports or generates educational properties and therefore wholeness,
4. **patterns** are general forms, or wholes, in which an interplay of structural properties manifests and therefore leads to (educational) values and wholeness, and
5. actual **implementations** of such patterns inherit these properties if and only if they maintain the structural properties, i.e. they do the right thing the right way.

We have said that our educational properties are emergent values. An interesting exploration would be to analyze the relations of all educational dimensions that have a structural nature, i.e. differentiate learning environments or educational spaces. Baumgartner (2011) has identified 29 such dimensions (e.g. time, group size, use of tools and media, participation, self-direction etc.), and each dimension is differentiated on an ordinal scale into five sections. If we consider a specific educational form (such as one of the lecture design patterns), we can locate the structure of this form in the 29-dimensional space implied by Baumgartner and see whether Alexander's fundamental properties can be found in that space. The difficulty of this approach is that it is difficult to imagine a manifestation in the 29-dimensional space. Each of the dimensions is meaningful for differentiating and distinguishing different educational forms. However, to consider all 29 dimensions for one form as a whole and in parallel is very difficult. One expectation would be that pattern descriptions could do exactly that because they describe one whole by analysing it.

One of the questions we have not answered yet is whether each lecture design pattern can be improved by having more of the fundamental structural properties or/and more of the educational properties. This was planned in the original scheme of our method but has not yet been addressed.

5.4. Reflections on applying the analysis method

We would like to have been able to present a polished method and to claim to have found an ultimate path to map the 15 properties for education, or rather any domain, but within the scope of this paper, this was not our intent. Rather we used the method as an experiment and indeed changed our approach at some points.

One deviation from our original plan made by one of the authors was to first look for occurrences of the 15 properties in lectures in general (instead of focussing on the five patterns). For example, lectures consist of many Strong Centers: Interesting lectures are a mixture of many different content types: definitions, demonstrations, arguments, questions, illustrations, statements, explanations, anecdotes, summaries, surprises and so on, whereas monotonous lectures are boring and dead. The mixture is spicy; each part enriches the others. The anecdote is meaningless if it is not set into context within an argument or a definition. The lecturer (or lecturers) constitutes a Strong Center, a person that connects with all students. Content is also a Strong Center. Students concentrate on the content provided. A lecture is one unit, a connected time slot of presentation activities that are all interrelated and strongly connected. The lecture itself is a Strong Center because it connects with many other activities: practice sessions, exercises, tests, and projects. Different media, including chalk-boards, projections, experimental setups and screens, also constitute strong centers, as they require students' attention.

This pre-evaluation of the 15 properties for lectures in general certainly influenced the later mapping of the properties as well as the identification of the properties in the particular patterns. Another deviation from our original plan was that we ended up not distinguishing between direct and indirect mappings for the properties. The reason is that we soon discovered that for each fundamental property, several mappings onto various educational properties existed. In the more specific analysis of the patterns, however, the fundamental properties were marked as a direct or indirect mapping.

While we did not follow our own proposed method exactly we did find that the method provided very good guidance for us to reflect on the meaning of the 15 fundamental properties for a given domain. Moreover, the method made it possible to identify the existence of the fundamental properties in good educational designs. However, this is not proof that these

properties always lead to positive educational effects. For example, in a teacher-centered educational setting the lecturer could be a Strong Center who dictates the pace, the content and the lecture flow. In such a situation we would hardly find Inspiration, Engagement, Excitement, Flow experiences, Motivation or Diversity.

The method presented in this paper is not the final word but it led to a deep reflection on Alexander's 15 properties in a structured and systematic way. It encouraged a discourse and brought new insights for both authors. One of the reasons for this is that the method required us to focus on specific tasks such as finding educational values, agreeing on the most important ones, mapping the properties and analyzing concrete patterns.

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