

# Leveraging Creativity as a Problem-Solving Tool in Software Engineering

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*// In this article, we port results from creativity research in the field of cognitive psychology to the field of software engineering. After all, programming is a highly creative endeavor. We explore how to leverage creativity as a practical problem-solving tool to wield for software developers. //*



**WHAT IS THE** difference between a good and a great software engineer when it comes to problem solving? Solving intricate programming problems on high-level architectural and low-level design levels requires mastery of multiple-domain general and

domain-specific hard and soft skills where creativity comes up on top as one of the most prevalent factors to successfully facilitate tackling difficult problems.<sup>1</sup>

Creativity can be used as a form of self-expression, for example, in creative coding sessions aimed at exploring and learning. Instead, in this article, we focus on creativity as

a practical tool to solve a problem. By emphasizing on the right combination between creativity and critical thinking, taking into account the context and constraints of the problem, creativity can be wielded as a powerful tool—not just as a goal in itself. In other words: *Creativity is the means, not the goal.*

Yet what exactly is creativity? According to cognitive psychologists, an idea is creative if it meets these descriptions: It is considered novel and original, it is of high quality, and it is relevant to the task at hand.<sup>2</sup> However, this essentialists' view on creativity does have its shortcomings, for example, by completely ignoring context. Recent advances in creativity research showcase a gradual shift toward a systemic approach where creativity can be seen as a social verdict,<sup>3</sup> meaning your peers decide whether or not your coding solution is considered creative.

This may sound like we have zero control of our own creative outcome and are at the mercy of our colleagues when it comes to achieving the label “creative.” Luckily, interviews and Delphi studies conducted by Groeneveld et al.<sup>4</sup> identified several distinct but highly intertwined domains of creative problem solving in context of software engineering (SE): 1) technical knowledge, 2) collaboration, 3) constraints, 4) critical thinking, 5) curiosity, 6) a creative state of mind, and finally 7) practical creative techniques. A summary is available in [Figure 1](#).

This article is part of a bigger project on exploring creativity in SE by Groeneveld et al.<sup>4</sup> who initially published the mind map in [Figure 1](#). Here, we provide a new practical view that translates the theory from previous publications into practical tools for software engineers. We

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believe that by taking advantage of these ideas, practitioners will be able to get unstuck when facing a complex problem. In essence, creativity can be leveraged as a problem-solving tool in SE.

The remainder of this article unfolds these seven creative problem-solving domains, providing new practical pointers on how to exploit them to help us become more creative programmers.

## Technical Knowledge

Can you approach a problem creatively if you do not have the necessary technical domain knowledge to do so? For example, consider this Go example code snippet:

```
func ToChannel(done <-chan struct{}) <-chan
any {
    c := make(chan any)
    go func() {
        defer close(c)
        select {
        case <-done:
            return
        }
    }()
    return c
}
```

Without some base level of Go's asynchronous channel concepts, it would be very challenging to refactor the previous piece of code, let alone borrow a channel concept to creatively deploy them in another language without that feature baked into it. And yet, that is exactly what many expert practitioners do and what their peers call creative, according to our interviews.<sup>4</sup>

Consider the birth of the Kotlin programming language. The engineers who designed the language

inspected and heavily borrowed concepts from existing programming languages. Kotlin features concepts of Java (classes, autoboxing, runtime safety guarantees, and so on), Scala (primary constructors, the `val` keyword, and so on), C# (ideas of `get/set` properties and extensions, and so on), and Groovy (the `it` shorthand).<sup>a</sup>

In one of our interviews while exploring the role of creativity in SE, a participant summarized his thoughts<sup>4</sup>:

The bottom line is that creativity is the brew of different inputs—and usually, I actively look up those inputs.

No input, no (creative) output. Yet gathering input alone is not sufficient: Research in the field of cognitive psychology has shown that for productivity levels to increase, one also has to internalize knowledge and act upon it.<sup>5</sup>

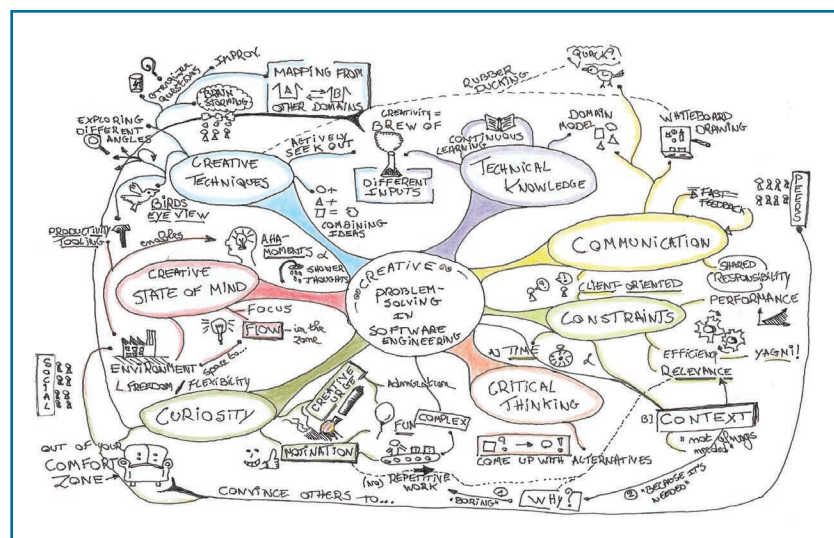
In sum, we have to cultivate a personal knowledge management tool where findings summarized in

our own words reside that can be connected to form new and exciting creative ideas. The aim here is to evolve loosely coupled information to tightly coupled knowledge and (new) insight. This is not only applicable for academics publishing papers, but also for developers publishing code, mastering languages, and writing technical articles.

## Collaboration

Does creativity exist in isolation? Collaborative teamwork—ideally, a heterogeneous group of people with different backgrounds and expertise sets—might end up radically changing the field they work in. For example, consider the mid-2000s Extreme Tuesday Club hosted by expert developers in London. The Club turned out to be a great breeding ground for several important and established SE techniques such as Continuous Delivery, Kanban, unit test mocking frameworks, and more. Additionally, other like-minded people in SE successfully mimicked the concept of the informal gathering, resulting in

<sup>a</sup>For more information, see Andrey Breslav's *Shoulders of Giants: Languages Kotlin Learned From* talk at GeekOUT 2018 at <https://youtu.be/Ljr66Bg-1M>.



**FIGURE 1.** A mind map that summarizes identified themes on creative problem solving in SE.

software craftsmanship meetups in every conceivable big city.

Contemporary SE heavily relies on teamwork. According to Csikszentmihalyi,<sup>5</sup> the creative power of the individual is negligible. Instead, organizations should focus on engineering pockets of creative collaboration, or what Johnson<sup>6</sup> calls *liquid networks*. Solid matter is tightly clustered together and allowed little wiggle room, while gas matter is too volatile to make ideas really stick. Instead, Johnson suggests we focus on creating a liquid network, as visible in the middle of Figure 2: One where ideas can bounce around and form new ones without risking to become too unstable. While Johnson's work is yet to be studied in SE, networks like the Extreme Tuesday Club proves the concept shows promise.

We are more creative when in the (virtual) vicinity of creative coworkers, yet at the same time, sometimes those very coworkers heavily impede our creative flow. Social issues in and around software development teams severely affects team performance. Tamburri et al.<sup>7</sup> call this phenomenon *social debt*, and just like the well-known *technical debt* describing the implied cost

of future code changes that comes with *code smells*, social debt has its own antipatterns called *community smells*.

The following selection of community smells as identified by Tamburri et al. demonstrates the principle and its destructive relation with creativity more clearly:

- *Lone wolf*—a person who does not take others' opinions into consideration and ignores rules set out by the team
- *Black cloud*—information overload and no way to manage information, resulting in the potential loss of creative ideas
- *Hyper-community*—a too volatile environment where no idea truly sticks or no time is given to thoroughly evaluate ideas.
- *Cookbook development*—developers stuck in their ways refusing to adapt to new technologies who are hostile toward new ideas.

A few dangerous combinations of the aforementioned smells will have a devastating impact on team morale, and thus, creativity. While openly and critically discussing ideas is good, an excess of conflicts is

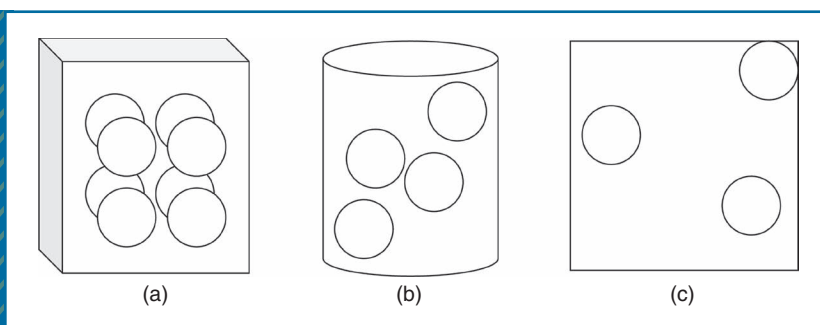
detrimental creativity. The transition from code smell to community smell does not require a big leap of faith: Many code smells find their root in community smells.

## Constraints

Can we readjust the constraints of a software development project in such a way that it increases the creative thinking throughput? Constraints do drastically improve creativity—up to a point. Too little and the endless sea of freedom indefinitely postpones our motivation to act. Too much and the stress level diminishes our creative thinking capabilities. Biskjaer et al.<sup>8</sup> suggest we aim for a sweet spot in-between both, as visible in Figure 3(a), to either impose new ones when we are feeling bored or try to reduce constraints when we feel stressed.

But before we can do that, we first have to identify different categories of constraints and how they manifest in SE. Elster<sup>9</sup> defines a taxonomy of constraints, as visible in Figure 3(b). The sweet spot and taxonomy concepts are domain-general, requiring further empirical evidence in SE, but our previous work suggests they do translate well into SE.

First, *intrinsic constraints* are inherent to the problem at hand. If you are a programmer, you will have to work with the software and hardware that is currently available to you. If you wrote programs in the early 1990s, chances of bumping against the hardware limit are much higher than nowadays machines, yet these tight constraints were also a source of inspiration. For instance, the Game Boy (GB) game X boasts a first-person true 3D polygonal rendered flight scene, while in 1992 was technically impossible to do 3D on the GB that on paper only supports 2D sprites. The developers managed to



**FIGURE 2.** A schematic of the liquid network principle. (a) Solid matter: ideas set in stone due to the definite shape and volume. (b) Liquid matter: allowing the creation of new connections. (c) Gas matter: too volatile to make ideas stick.

successfully bend those intrinsic hardware constraints to their advantage.

Second, *imposed constraints* are constraints handed out by a stakeholder. For example, typical budget or time constraints as agreed upon by customers and management are part of this category. While the difference between intrinsic and imposed constraints is subtle—they are both grouped together as *incidental constraints*—there is a big psychological difference. We would rather accept contemporary hardware constraints than constraints we were told to adhere to. Successfully working with and transforming legacy code falls within this category. Modern software development techniques applied to older programming environments are the prime example, such as *Test4z*<sup>b</sup> that enables unit testing for mainframes.

Third, *self-imposed constraints* are constraints we add ourselves to deliberately push our creative problem-solving skills to the limit. Limitations can be seen as a guide to your creative solutions. Many game developers are still creating new games for

older hardware because these tight constraints force them to come out of their comfort zone. Purposely writing methods with three or less arguments and 20 or less lines of code to force yourself to think about responsibilities and clean code is another example of self-imposed constraints, as is the philosophy and deliberately simple design of the Go programming language.

### Critical Thinking

When are software developers not so creative? According to the practitioners we interviewed, when they blindly take over answers from AI-powered code generation tools, when alternatives are not being considered, when just their tasks are being ticked off, and when repetition kicks in. A participant elaborates:

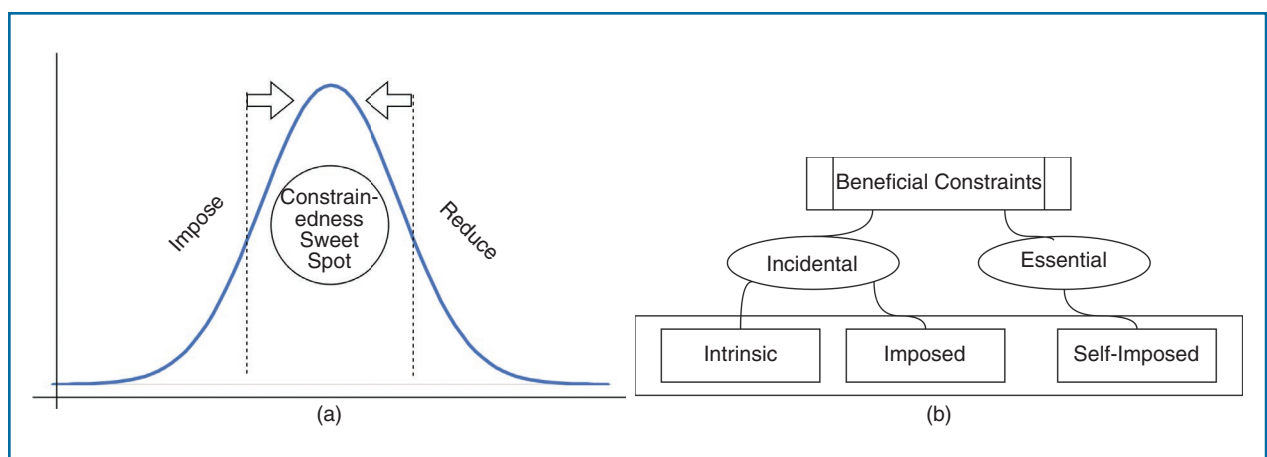
“[I am not creative when] I just try it until it works, such as fixing dependencies.”

Many interviewees emphasize the importance of critically evaluating and iterating on ideas. This *verification* step perfectly matches one of the five stages of the creative process as first identified by Graham Wallas<sup>10</sup>:

1. *Participate*—The bulk of the work happens here.
2. *Incubate*—The creator takes a bit of distance from their work and interrupts the process to facilitate insight.
3. *Illuminate*—The “aha”-moment (see “Creative State of Mind” section) that will not happen without the sweat of the *participate* step.
4. *Verify*—Critically evaluating and iterating on ideas.
5. *Present/accept*—The solution is only creative if your peers accept it (see “Introduction”).

This process is recursive where any step (except for final step 5) might jump to any other step. Csikszentmihalyi suggests that taking a step back to critically evaluate your creation is one of the key aspects to creative success. For a software developer, this is equally important as they rely on (automated) tooling to facilitate the iterative evaluation step: unit tests that turn red or green in the pipeline after each commit, fitness tests that pass or fail to signal architectural problems, and so on.

<sup>b</sup>See <https://mainframe.broadcom.com/test4z/>.



**FIGURE 3.** Behavior and taxonomies of constraints. (a) The constrainedness sweet spot. (b) The taxonomy of beneficial constraints.

Skipping on the verification step leads to critical thinking fallacies that in SE often result in common coding mistakes. Hermans<sup>11</sup> collected many of these mistakes based on interviews and empirical studies in the SE industry. For example, many developers rely on *transfer during learning* to pick up a new language: type inference in Kotlin (`val myArr = arrayOf(1, 2)`) helps reducing the jump to JavaScript's dynamic duck typing (`let myArr = [1, 2]`). However, that transfer can also lead to *cross-language interference*. The usage of the `const` keyword in Kotlin creates compile-time constants to primitives and strings. In JavaScript,

interviews exploring the role of creativity in SE, curiosity is often cited as a core proponent of creativity. A participant found his colleague to be more creative than himself because they were frequently reading new books, reading articles, and trying out new programming languages.

Without staying curious, less new technical knowledge will be gained (“[Technical Knowledge](#)” section), decreasing the chance of idea forming and merging. Without perseverance, imposed constraints will start to weigh (too) heavy (“[Constraints](#)” section) and the iterative creative process from the “[Critical Thinking](#)” section will yield less polished results.

Creativity can be used as a form of self-expression, for example, in creative coding sessions aimed at exploring and learning.

`const` defines a runtime constant reference to a value: You can still push new values to a `const` array.

## Curiosity

Can we motivate software developers to become more curious, and thus in turn more creative? Research by Csikszentmihalyi reveals that curiosity and perseverance play a major role in creative success, while Gross et al.<sup>12</sup> highlight that although empirical evidence for the curiosity-creativity connection is scarce, curiosity may indeed benefit creativity.

Experiments in SE education also suggest that creative students get out of their comfort zone more often than their less-creative peers.<sup>13</sup> In our own

Many software developers we interviewed keep themselves motivated by what they call “fooling around” in their free time: discovering new languages, frameworks, and techniques by programming playful, small diversions. They are having fun and learning new things at the same time, not necessarily leveraging creativity to solve a problem at hand, but using their curiosity to further feed their creative craving. Employers can further support this by organizing reading groups, hackathons, and knowledge-sharing afternoons. In the ever-changing landscape of SE, continuous learning has become critical to effectively work, communicate, and innovate on an international scale.

## Creative State of Mind

How can software developers generate more insights? As mentioned in the “[Critical Thinking](#)” section, no Eureka effect without ample blood, sweat, and tears. Yet getting in the right creative mood does wonders for the frequency of new ideas that “suddenly” pop up in our minds. Again, a great body of research work has been published by Mihaly Csikszentmihalyi on how to achieve a state of what he calls flow or the *optimal experience* (Csikszentmihalyi, 1997).<sup>5</sup>

In order for this flow state to occur, just the right amount of challenge combined with skill level is required. Too challenging, and we experience anxiety. Too little challenge and too high skill level, we will feel bored. When we interviewed software engineers on the requirements to be creative, they answered in vaguer terms such as *if everything feels right* and *the feeling that you're really in the [flow] zone*, hinting at Csikszentmihalyi's optimal experience.

According to our SE respondents, the environment plays a major role in facilitating flow. Some jump in their car to think while others take a shower or go for a run. By not actively thinking about the problem, they *are* actively thinking about the problem: This is the incubate step of the “[Critical Thinking](#)” section.

Corporate environments or home offices of software professionals should provide the necessary flexibility and freedom to help keep the flow flowing, even though workspace and decorations are highly subjective. Thorning et al.<sup>14</sup> compiled a list of unique space types that should be present in each work environment to maximize creative potential:

- a private space to focus
- a collaborative and/or making/experimentation space
- an exhibition and/or presentation/sharing space
- a relaxation space
- an unusual space that might trigger insight
- an incubation and reflection space.

Strictly separating these spaces and their temporary inhabitants is important: Excessive interrupts from your private focus space can negatively impact the creative process, especially for information workers.

### Creative Techniques

Creative SE work is boosted by employing various practical tools and techniques, such as the aforementioned analogy technique [mapping solutions from another domain (“[Technical Knowledge](#)” section) or actively seeking out feedback, both self-reflective and external (“[Collaboration](#)” section)]. Our interviewees regularly mentioned these techniques in context of problem solving.

A more thorough exploration of the usage of creative techniques in SE was conducted by Bobkowska<sup>15</sup> using a training-application-feedback cycle. According to the authors, the best creative results were achieved by leveraging a mix of these techniques. The identified techniques are grouped into four themes: 1) *interpersonal skills* (see the “[Collaboration](#)” section), 2) *creativity skills* such as associative thinking, 3) *motivational skills*, and 4) *overcoming obstacles*. The following selection illustrates some of the techniques:

- *Let’s invite them*: What if we invite, for example, Joshua Bloch, one of the lead architects of the Java platform—what would he suggest we do?



## ABOUT THE AUTHOR



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- *What if...*: What if we did not need distributed transactions—how would we tackle the problem then?
- *Reverse brainstorming*: What don’t we like about our current distributed transaction implementation?
- *I could be more creative if...*: What if the organization encouraged a more flexible work plan to facilitate flow?

These thought experiments can be conducted individually or in group.

In this article, we zoomed in on a systematic view of creative problem solving in SE that consists out of seven distinct but heavily intertwined domains: *technical knowledge*, *collaboration*, *constraints*, *critical thinking*, *curiosity*, *cultivating a creative state of mind*, and *practical creative techniques*.

Software practitioners can overcome difficult problems that typically arise when developing complex software systems by wielding and combining the tools as discussed. For example, approach situations from different angles by adding more constraints or taking a few away, and when stuck. Be on the lookout for new input to get that creative brew going. Stimulate or introduce other knowledge domains that

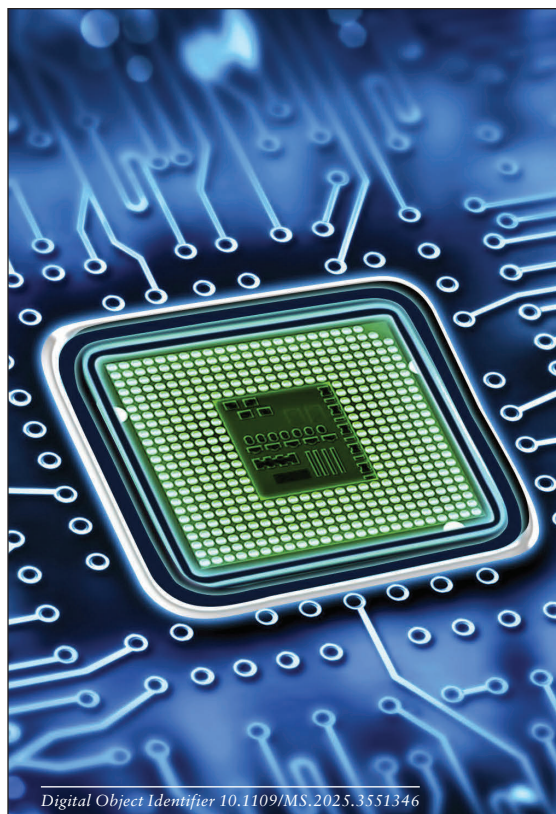
might generate original approaches to tackle the problem. Be mindful of interruptions and agree on how these should be tackled. Integrate moments of playful discovery in your professional life. Identify and explicitly discuss social debt next to technical debt in retrospectives.

But most of all, remind your SE colleagues that creativity is an attainable skill: Just like programming, it can be learned with practice and patience. 🍷

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