



Northeastern University
Khoury College of
Computer Sciences

Skills and Expertise in CSGs / HCGs

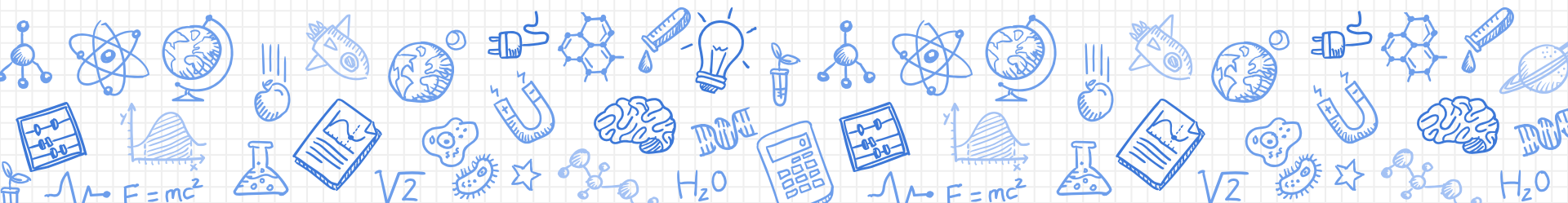
Josh Aaron Miller



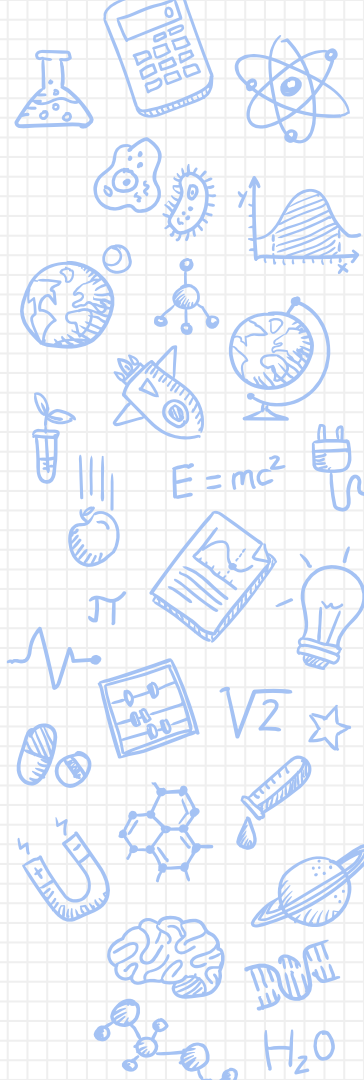
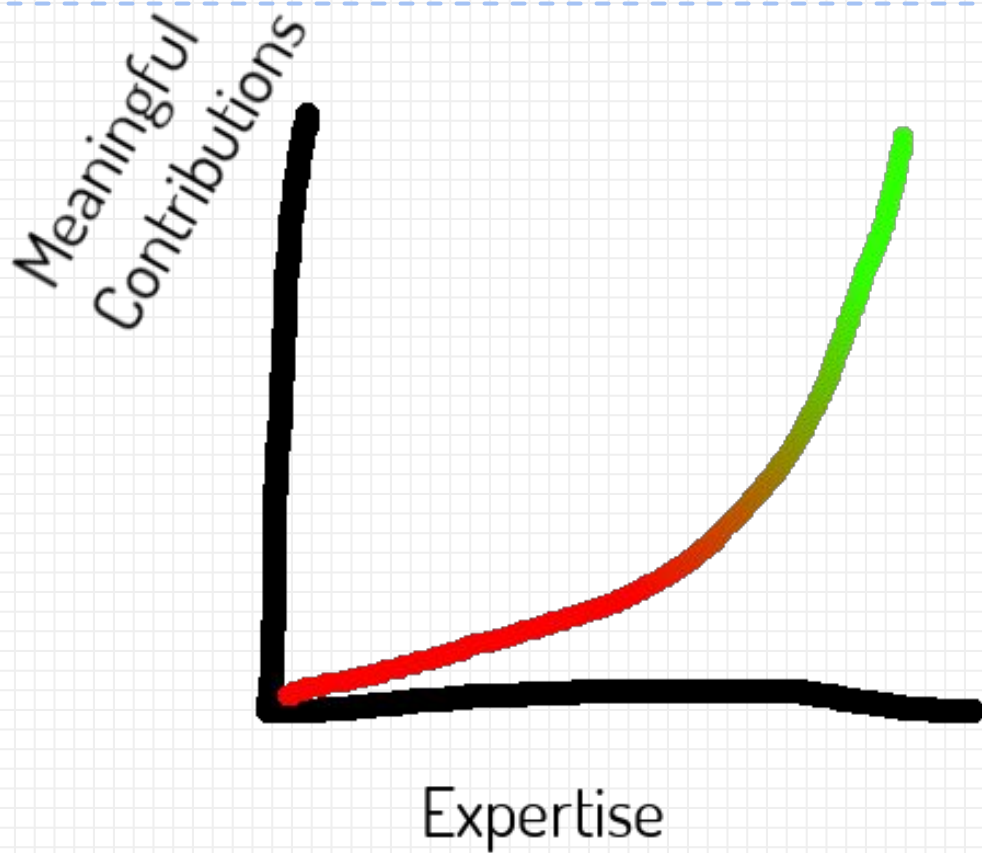


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Why do skills and expertise matter?



Expertise in HCGs



Expertise in HCGs

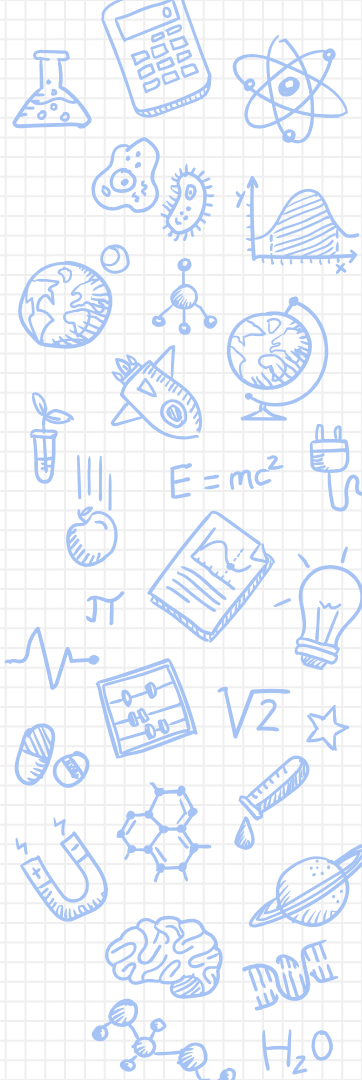
YOURCASE

The Wolf and the Crane (Aesop)

Total number of phrases	25
Correct phrases you agreed with	9 ✓
Incorrect phrases you disagreed with	3 ✓
Correct phrases you disagreed with	2 ✗
Incorrect phrases you agreed with	11 ✗
Your new rating is	48% ❤️

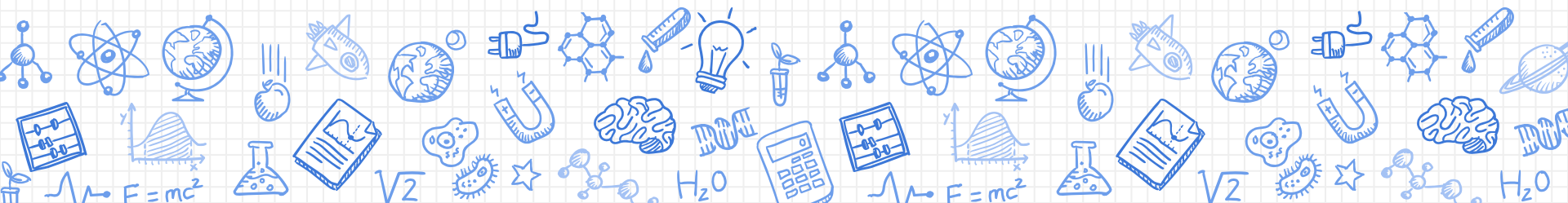
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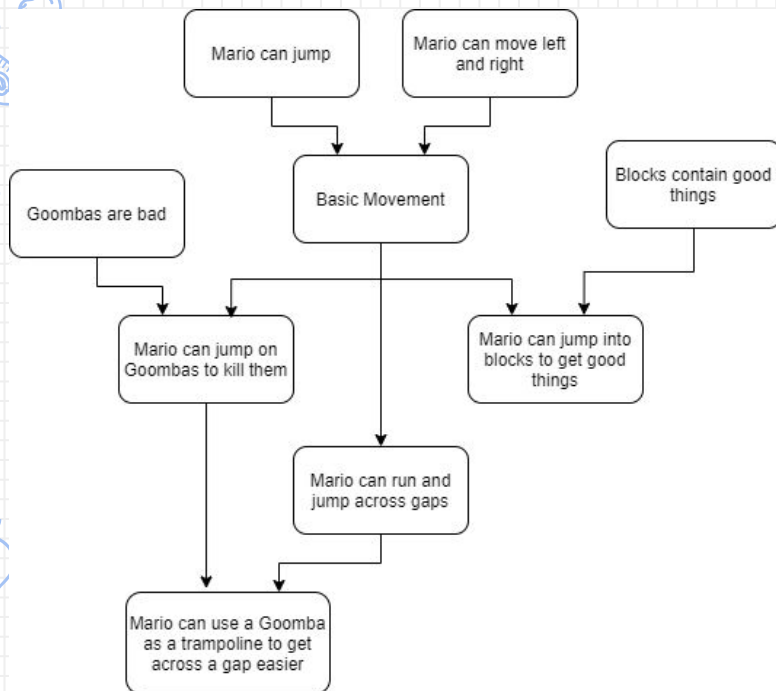




Using skill chains to understand expertise



Skill Chain



Skill Tree



- Outline of onboarding requirements
 - Knowledge tracing

- Outline of onboarding requirements
 - Knowledge tracing
- Identify breakdowns during playtesting
 - Dynamic tutorials

- Outline of onboarding requirements
 - Knowledge tracing
- Identify breakdowns during playtesting
 - Dynamic tutorials
- Help players track progress
 - Personalized learning

Easier Said Than Done



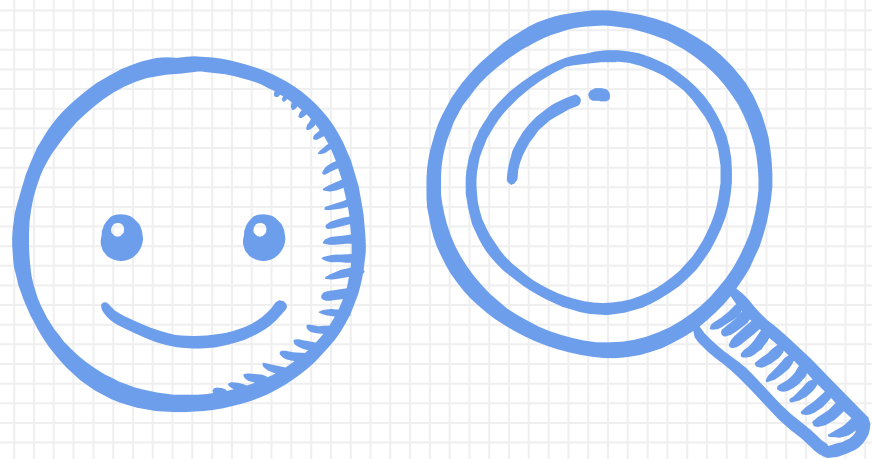
-

Easier Said Than Done

- ✗ Typically made manually by developers
- ✗ Can be done by intensive CTA methods

(Cognitive Task Analysis)





Direct Elicitation

What if we just asked them?

1. Do players and developers share the same understanding of the skill chain?

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2. How do players and developers conceptualize the skills gained through play?

1. Do players and developers share the same understanding of the skill chain?
2. How do players and developers conceptualize the skills gained through play?
3. Is direct elicitation effective for understanding a game's skill chain?

Skill Chains (# Interviewed)

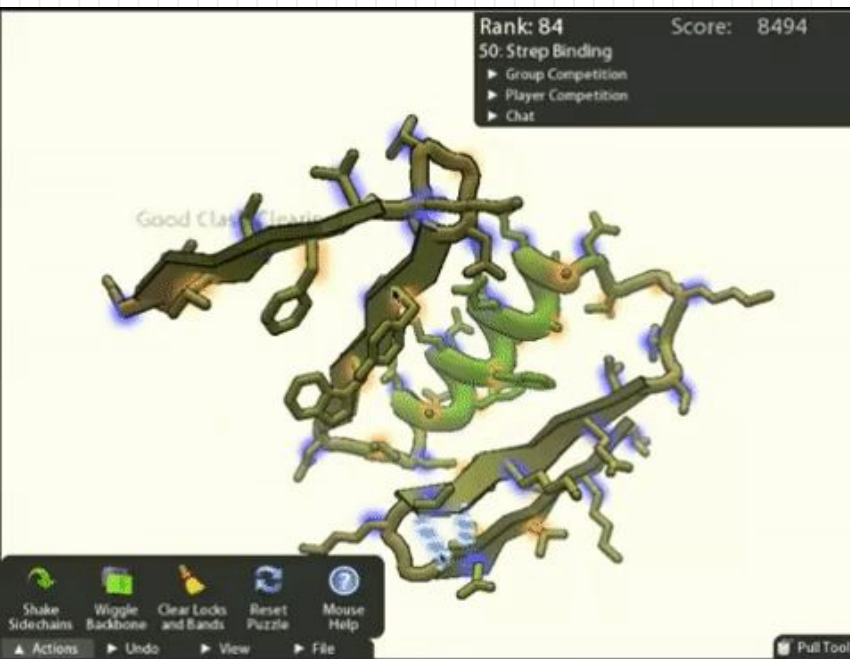
Game	Novice players	Expert players	Developers
Foldit	4 (1)	6 (3)	2
Eyewire	0	3 (1)	1
Eterna	0	3 [†] (3)	3 [‡] (3)
Total	4 (1)	12 (7)	6 (3)

One chain was in two parts

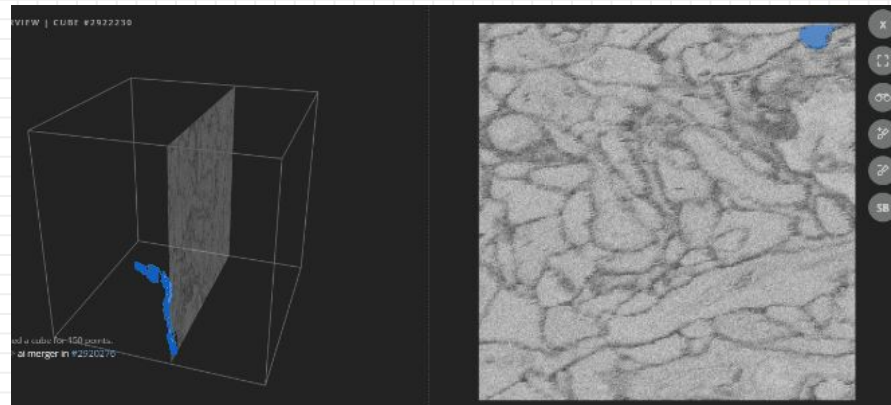
Also experts as players!

Games of Interest

Foldit



Eyewire



Eterna



Procedure

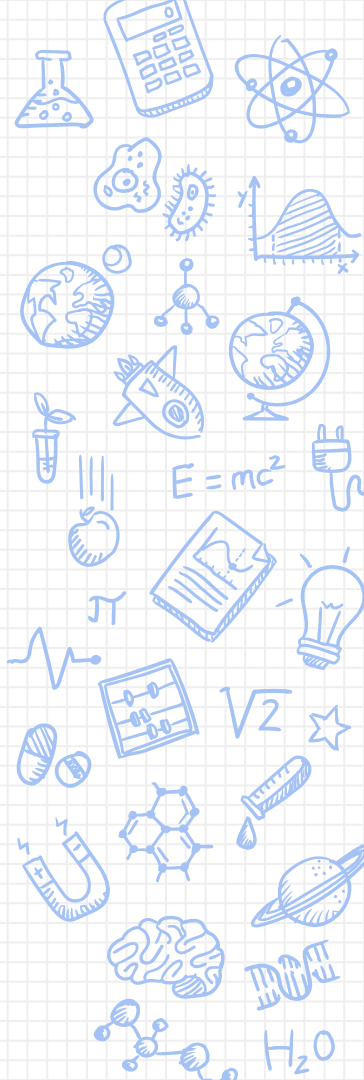
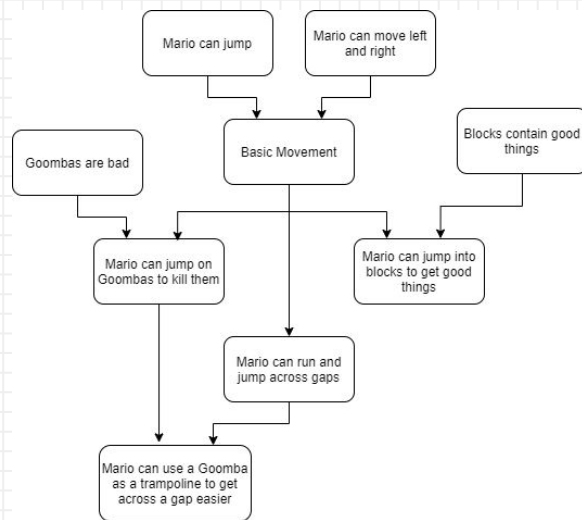
1. Read an article about skill chains

- a. https://www.gamasutra.com/view/feature/1524/the_chemistry_of_game_design.php?



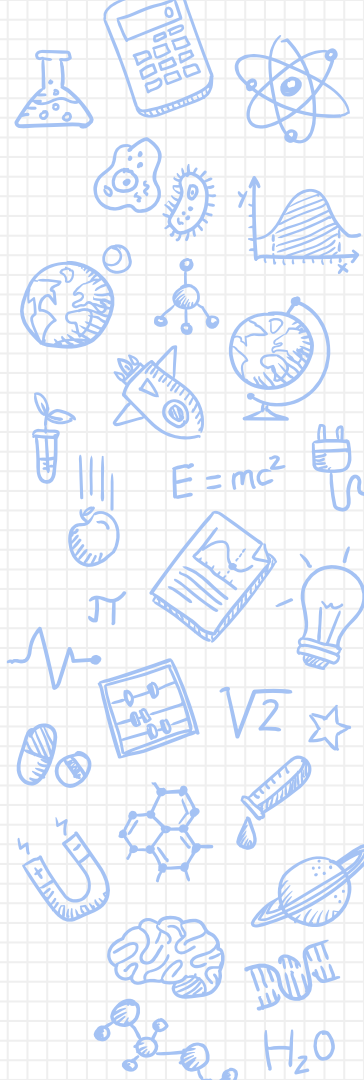
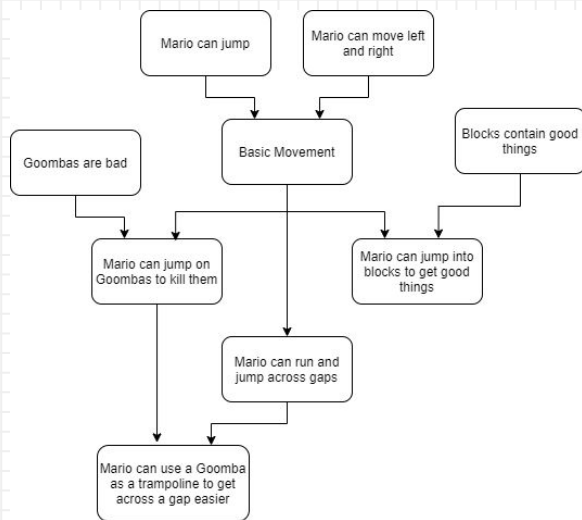
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 - a. draw.io suggested



Procedure

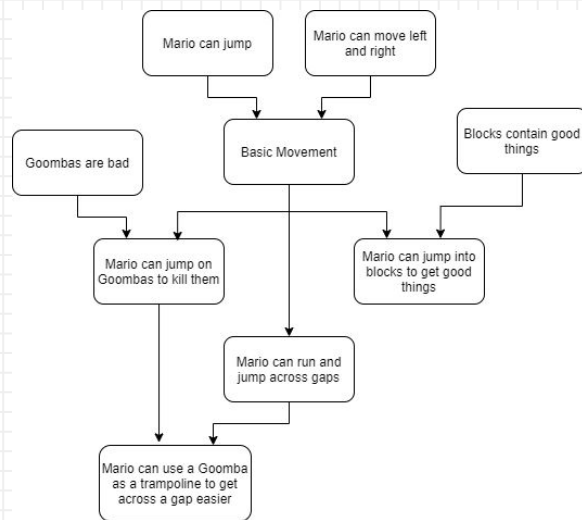
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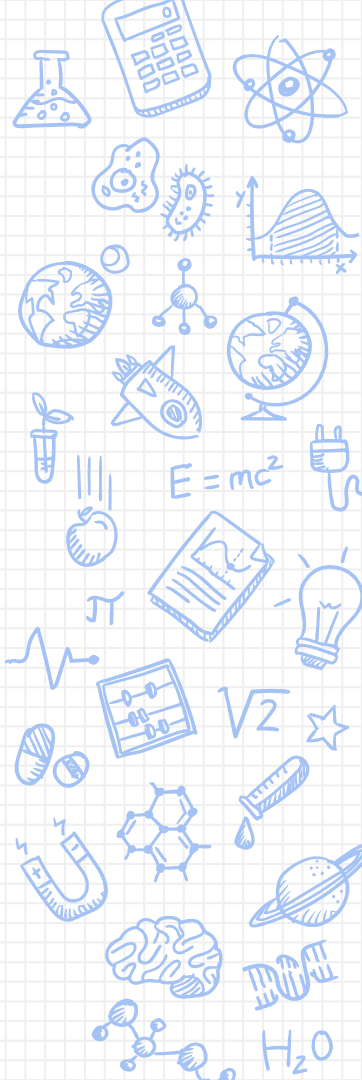
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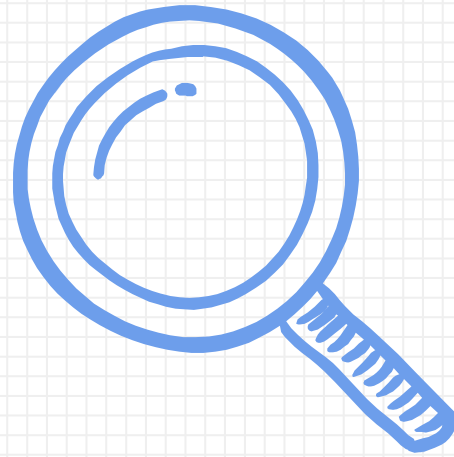
3. Make a skill chain

a. draw.io suggested



*3 novices first played Foldit
(30 min. tutorial; 10 min science)





Analysis

How do players and developers conceptualize the skills needed to play CSGs?

How do players and developers conceptualize the skills needed to play CSGs?

- Assume skill chain model
- Assume 1 label per node

Category	Description	Example*
Actions	Any tool or in-game ability the player can use; a single player input	Freeze
Practice	The act of repetition or continual play, especially with a focused goal, often to sharpen soft skills in the game	Practice coloring
Procedures	A specific sequence of actions or a combination of inputs	Rubber bands pull sheets together
Strategies	A high-level plan for reaching a goal; unlike Procedures, a Strategy does not specify a particular sequence but instead provides heuristics and guidelines such as if/then statements with freedom regarding how the goals are to be executed; this category also includes specific decisions made during the strategizing process	Hand fold[ing]
Guidance	Any instruction or assistance provided to a player, either from the game (such as tutorials, feedback, tooltips, and paratexts such as wikis), or between players (such as mentorship)	Press W to wiggle the protein
Discoveries	Any observations which affect the player's mental model, such as learning new game rules, experiencing epiphanies about the effectiveness of different strategies, or noticing informative details in the game state	Clashes ... are bad
Social	Collaborations, competitions, or communications with other players	Competition is fun
Objects	Any specific game element, resources, or in-game entities and concepts	Score
Motivation	Any goal, reward, or other motivating factor that the player considers; these are combined because the player uses motivation to inform a goal which leads to a reward which satisfies the motivation in a continuous, repeating cycle	Rank seeking

Categories Compared to Prior Work



Categories of This Study	Cook's Atoms	Deterding's Atoms	P11, Eyewire Player Legend	P6, Foldit Player Legend	P9, Foldit Player Legend	P10, Foldit Player Legend
Actions	Action	Actions	Player Action	Action	Controls / Actions	Player Action
Practice	-	-	-	Investment (personal & community)	-	-
Procedures	-	-	-	-	Side Issues*	-
Strategies	-	Challenges**	Player Decision	-	-	-
Guidance	Feedback	Feedback	-	-	Definition / explanation	Veteran / Science Input
Discoveries	Modeling	Rules**	-	-	-	Player thought
Social	-	-	-	Social	-	-
Objects	Simulation	Objects	Game Information	-	Concepts	Visual Element
Motivation	-	Goals, Motivation	-	Incentives	-	-

Single-Coder RTA

How do players and developers conceptualize the skills needed to play CSGs?



How do players and developers conceptualize the skills needed to play CSGs?

- ✗ Don't assume skill chain model
- ✗ Don't assume 1 label per node

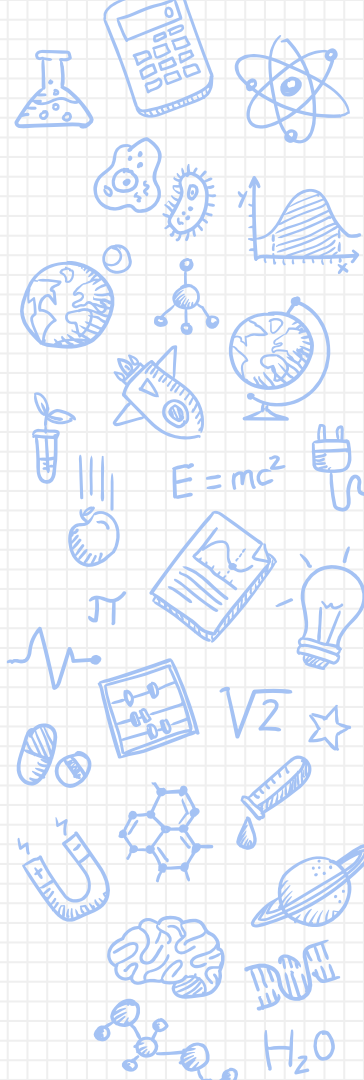
Four themes:

1. Experts are Experiential Learners
2. The Process of Playing
3. Tutorials as Passive and Standard
4. Knowledge Framing

Experts are Experiential Learners

Observations lead to current behavior

“Attaching bands by hand seems easier when something is wiggling, so I often wiggle sidechains when attaching bands by hand.” (P7, Foldit Player)



Experts are Experiential Learners

Experts gain an intuitive “eye”, or *professional vision*

“...I intuitively know rather than understand and play from how the pattern looks and feels more than from my scientific knowledge, which is apparently improving but not in conscious ways. The key to my own way of playing foldit is how a pattern looks rather than knowing why it folded up correctly from a scientific point of view.”

(P8, Foldit Player)

Experts are Experiential Learners

Experts remember discoveries

*“Realizing the importance of hydrogen bonds in making good structures from B-strands. **Puzzle 630...really brought this idea home.**” (P7, Foldit Player)*



Experts are Experiential Learners

Using community-creating knowledge and paratexts

*“further informations: notifications, Eyewire **blog**, Eyewire **forum**, Eyewire **wiki**, Eyewire museum”* (P11, Eyewire Player, punctuation added for clarity)

*“The **Black Belt Folding videos** showed me the value of using the Selection Interface...”* (P7, Foldit Player)



Experts are Experiential Learners

Referencing external background knowledge

“Other [scientific] models exist with different parameters and behaviors” (D6, Eterna Player/Developer)

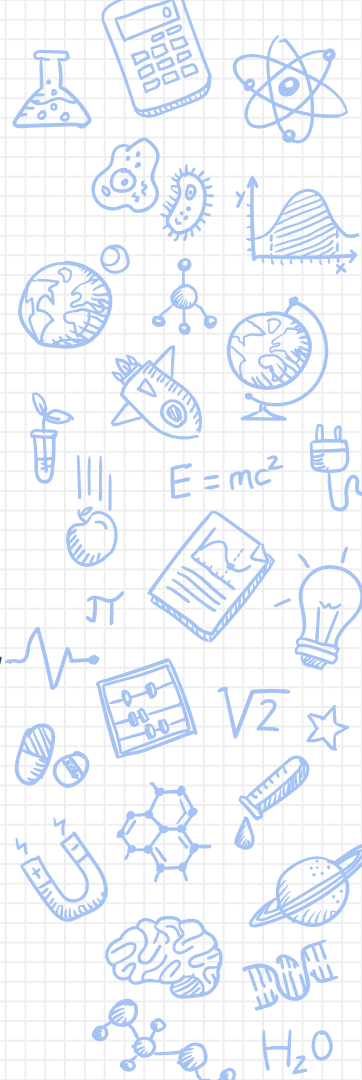
“Hydrophobic: ‘Water hating’ sidechains...do not bond well with water... Hence, most proteins in solution will have hydrophobic proteins facing inwards...” (P9, Foldit Player)



Experts are Experiential Learners

Emphasizing the Big Picture

*“The barebones basics of what even is a protein, what are the rules of folding, and what we should be looking for when folding... emphasizes **the background knowledge needed to understand what even is “good” in this game... keeping players focused on the big picture....**” (P10, Foldit Player)*



Experts are Experiential Learners

Need for Dedicated Practice

“...*learning by doing* experience...” (P6, Foldit Player)

“User sent to *practice cube*...x5” (D3, Eyewire Developer)



Self-Reflection

*“EARLY game experience: Frustrating tutorials, crappy early beginner puzzle results, stab in the dark work on some intermediate puzzles, more frustration... **Learning what works... My ED [Electron Density] skills are very poor, but I see them slowly improving...**” (P8, Foldit Player)*

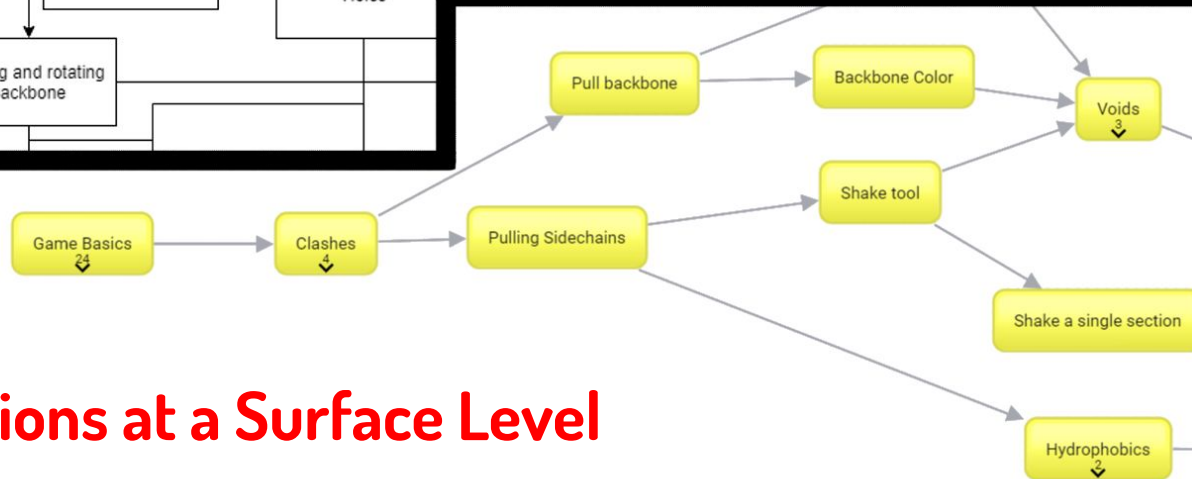
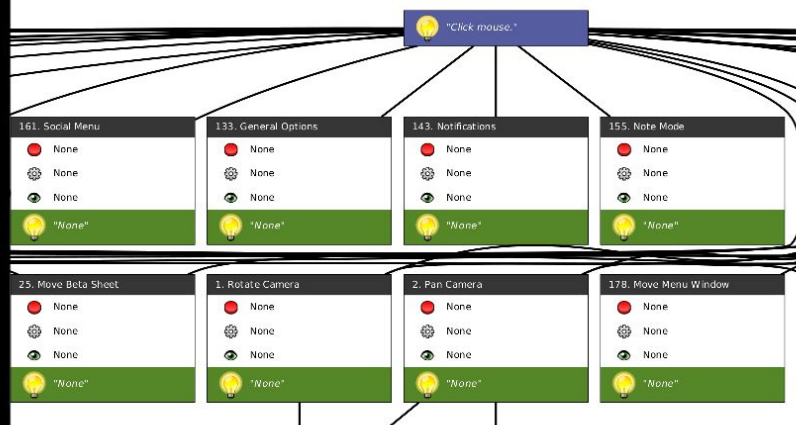
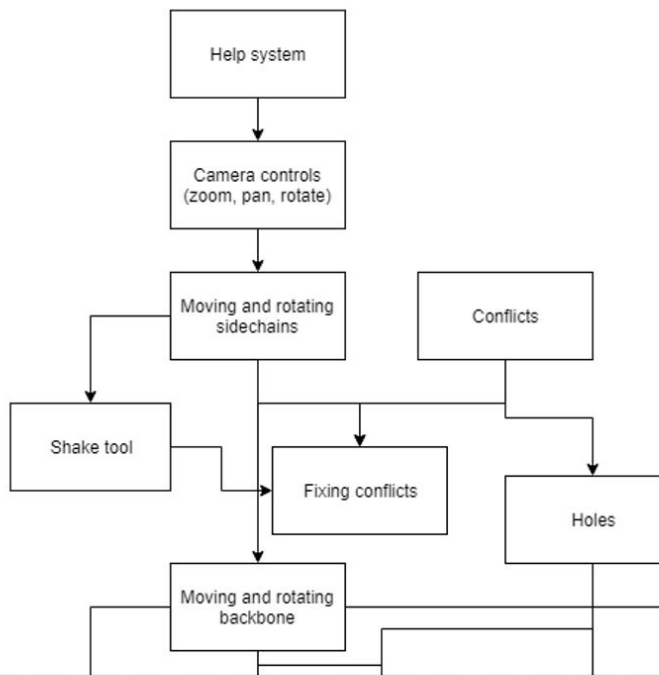
"If things seem stuck (like when hand-folding), use a low clashing importance to help things move to where you want them.... Sometimes you have to accept a loss in score in order to raise the score... if you are making a major change by hand, it often helps to do some wiggling and let the score fall a bit before starting your next recipe..." (P7, Foldit Player)

Interactions at a Surface Level

Novices and Developers

Interactions at a Detailed Level

Experts and Player/Developers



Interactions at a Surface Level

Interactions at a Detailed Level

“Secondary structure controls...Right click the restructured residues -> Ideal SS... **Sheets will require another sheet to form hydrogen bonds (you can form one by making the protein do a hairpin and go back the other way)**...For design puzzles, secondary structures can alternatively be assigned using the Blueprint tool...”
(P9, Foldit Player)

Equating the Tutorial with the Onboarding Experience



Tutorials as Passive and Standard

Describing the Novice Journey

*“**Start: What am I looking at...** The Protein (I assume)... Okay, so there’s point’s [sic] and stuff. Gonna need to raise it... **But how do I actually move things?**... So this score changes in real time based on what I’m doing. Noted. **I don’t wanna sit here and drag every sidechain though...** It’d be pretty tedious and boring if you had to go through and manually drag every sidechain, so we have the Shake tool! ... **Wiggle is awesome! Why don’t we just use this all the time? ... Situations where Wiggle doesn’t work...**” (P10, Foldit Player)*

Knowledge Framing

Motivation

Foldit/Eyewire

Flowcharts, Task Diagrams, and Structural Nodes

All



Motivation

“User receives points and is shown place on the leaderboard... Motivation increases” (D3, Eyewire Developer)

“achievements... millionaire milestones...” (P12, Eyewire Player)

“High score... Competing online... Contributing to science...” (P3, Foldit Novice)

Knowledge Framing

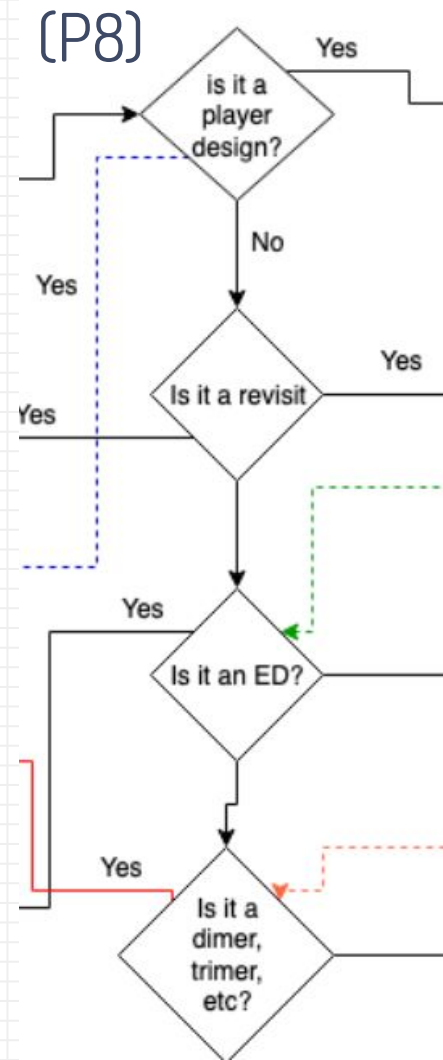
Flowcharts, Task Diagrams, and Structural Nodes

"Advanced Techniques" (D1, Foldit Developer)

"More Successes" (D4, Eterna Player/Developer)

"Main Techniques (Hand-Folding)" (P10, Foldit Player)

"Tutorial Stage" (P16b, Eterna Player)



1-6 hours, sometimes across days

1-6 hours, sometimes across days

Making chains

1-6 hours, sometimes across days

Prep work

Replaying tutorial

Method Reflection

Making chains

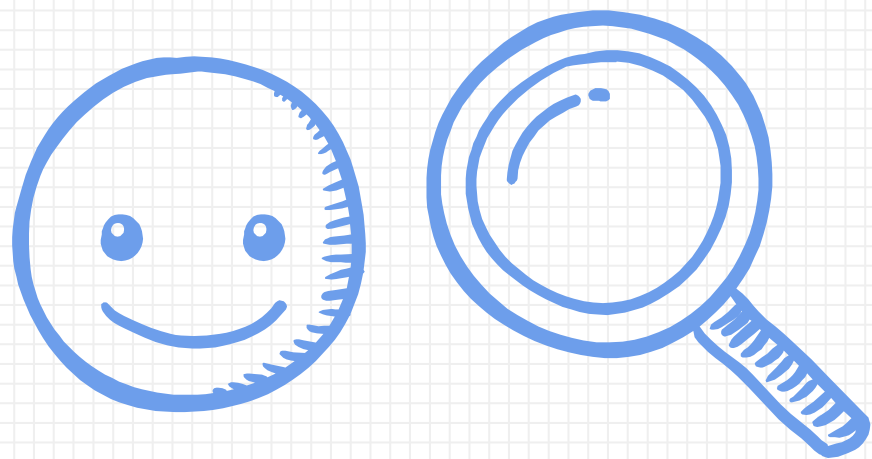
1-6 hours, sometimes across days

Prep work

Replaying tutorial

Uncertainty about desired output





Final Results

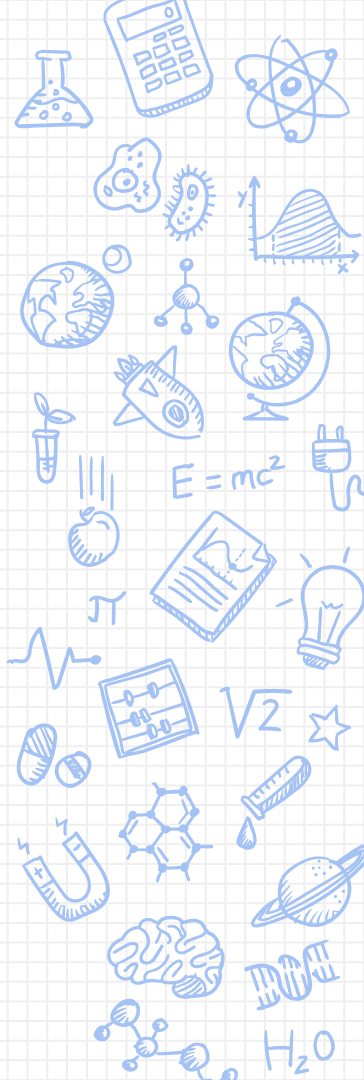
The answers to all our RQs

Do players and developers overlap in their definitions of the skill chain?

Yes, but those definitions reflect existing tutorial structure.

Discussion

How do players and developers conceptualize the skills gained through play?



Discussion

How do players and developers conceptualize the skills gained through play?

1. Tutorial-oriented
 - a. *Tutorials as passive and standard*
 - b. Describing *The Process of Playing*, at the surface



How do players and developers conceptualize the skills gained through play?

1. Tutorial-oriented
2. Core loop
 - a. Describing *The Process of Playing*, surface and detailed

How do players and developers conceptualize the skills gained through play?

1. Tutorial-oriented
2. Core loop
3. Stream of Thought
 - a. A glimpse at the expert's *Experiential Learning* experience

How do players and developers conceptualize the skills gained through play?

1. Tutorial-oriented
2. Core loop
3. Stream of Thought
4. What You See Is All There Is (WYSIATI)
 - a. Describing *The Process of Playing*, at the whole surface

Is direct elicitation effective for understanding a game's skill chain?

Sort of.

Discussion

Skill Conceptualizations



Discussion

Skill Conceptualizations

1. **Actions:** atomic interactions





2. Procedures: sequences of actions

-

-

Implications for Design



-

1. Give the big picture up front
2. **Embrace social learning and paratext use**

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3. **Reinforce the intended structure of knowledge**

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4. **Situate learning within applicable, meaningful contexts**

Implications for Design

1. Give the big picture up front
2. Embrace social learning and paratext use
3. Reinforce the intended structure of knowledge
4. Situate learning within applicable, meaningful contexts
5. **Design for discovery and self-reflection**



1. Give the big picture up front
2. Embrace social learning and paratext use
3. Reinforce the intended structure of knowledge
4. Situate learning within applicable, meaningful contexts
5. Design for discovery and self-reflection
6. **Encourage practice and learning beyond the tutorial**

Limitations and Future Work

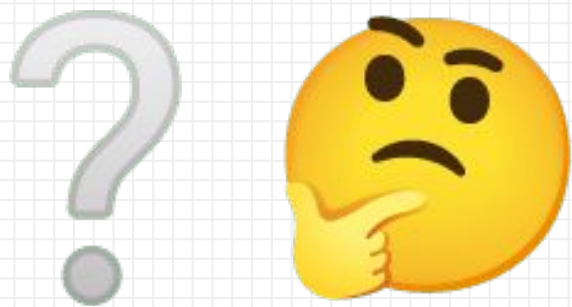
1. Generalizability / Sample Size
2. **Lack of Instruction / Uncertain Outputs**
 - a. Crowdsourced elicitation?
 - b. Structured recall?



Limitations and Future Work

1. Generalizability / Sample Size
2. Lack of Instruction / Uncertain Outputs
3. **Limited by Effectiveness of Current Tutorials**
 - a. Social/exploratory learning by necessity?

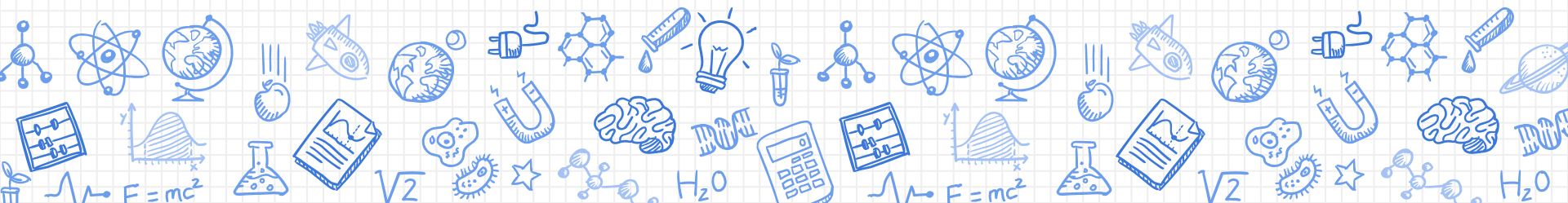




Questions?



Barriers to Expertise in Citizen Science Games



Citizen Science Games (CSGs)

- ✓ Produce scientific data



Citizen Science Games (CSGs)

- ✓ Produce scientific data
- ✓ Provide public access to scientific and societal challenges



Citizen Science Games (CSGs)

- ✓ Produce scientific data
- ✓ Provide public access to scientific and societal challenges
- ✓ Opportunity for public STEM education



Making someone an expert is very, very difficult.

What is the path to expertise in ECCSGs?

What are the major barriers along that path?

Background

Little attention has been given to CSG player experience, but here's what we have learned:



Background

Little attention has been given to CSG player experience, but here's what we have learned:

1. **Intrinsic motivation -> participation**

- a. Eveleigh et al. 2014; Haythornthwaite 2009

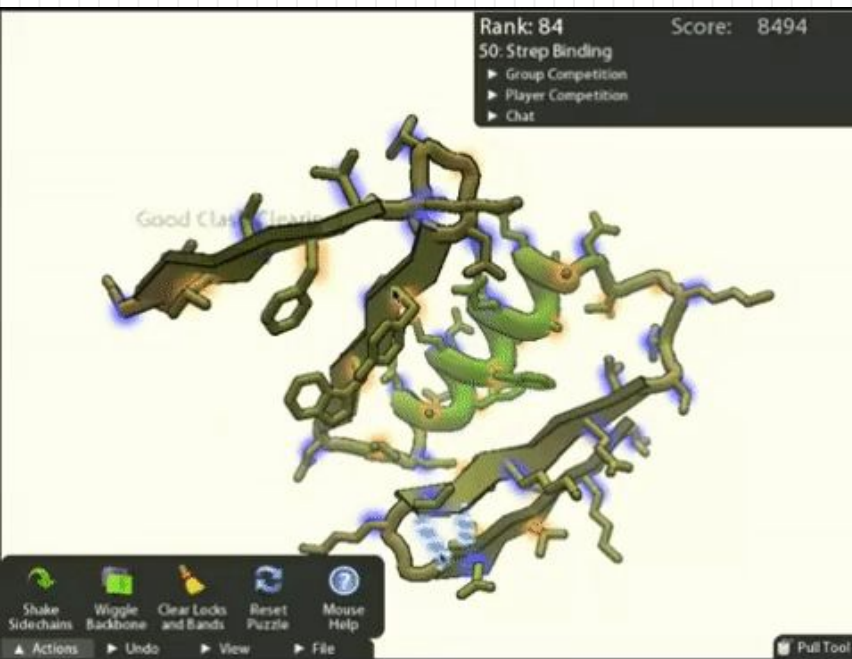


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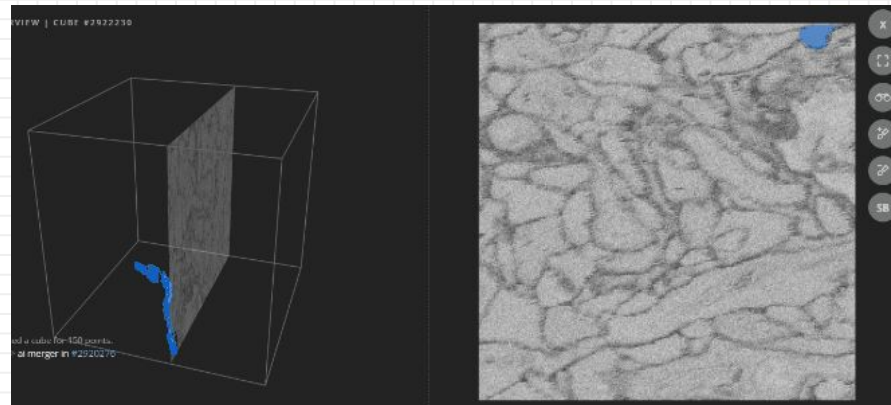
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Games of Interest

Foldit



Eyewire



Eterna



16 ECCSG players, semi-structured interviews

- 12 Foldit
- 3 Eterna
- 1 Eyewire

- 12 Foldit
- 3 Eterna
- 1 Eyewire

16.2 hours of audio transcription (M=60.75 min; SD=11.86)

Methods

16 ECCSG players, semi-structured interviews

- a. 12 Foldit
- b. 3 Eterna
- c. 1 Eyewire

16.2 hours of audio transcription (M=60.75 min; SD=11.86)

Asked about play experiences & game skills;



Resulting Themes

What's the Path to Expertise?

Social and Exploratory



Missing Open Communication

Game Design Barriers

Missing Polish

Resulting Themes

Social and Exploratory

Missing Open Communication

Missing Polish

Instructional Barriers

Missing Instruction



The Path to Expertise is Social and Exploratory

Expertise is social

Expertise is exploratory

**Dual motivators of continued engagement:
Science and Self**

Professional vision



The Path to Expertise is Social and Exploratory

Expertise is social

*It's a combination of, like, **messing around** and then looking it up somewhere else and **asking somebody**. (P11, Foldit, Intermediate)*

*There's a **community of veterans** that you're stepping into who can **share information and encouragement**. (P9, Foldit, Expert)*



Expertise is exploratory

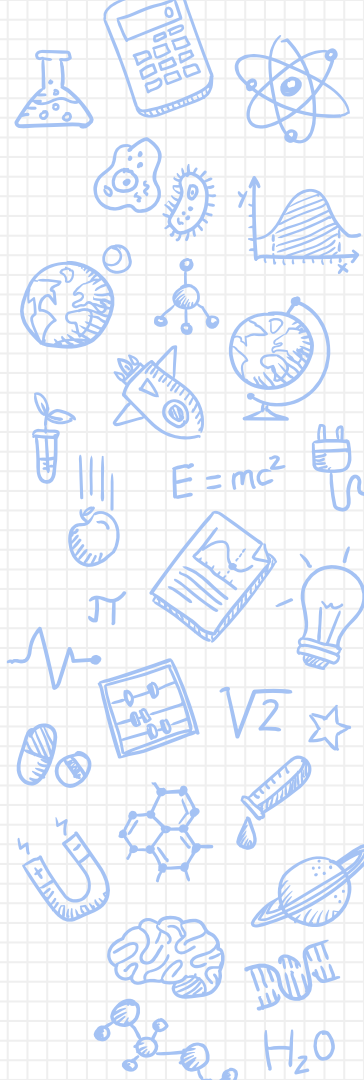
*Most of the expertise that you need to operate the game do not appear in the tutorial. They are gained from **experience and trial-and-error**. (P13, Eyewire, Intermediate)*

I have to struggle with it before it has any meaning to me to look it up online. (P5, Foldit, Novice)

The Path to Expertise is Social and Exploratory

**Dual motivators of continued engagement:
Science and Self**

*The chance to **both do hard puzzles and contribute to science**. It's really what got me interested and what has kept me interested. (P9, Foldit, Expert)*



The Path to Expertise is Social and Exploratory

Professional vision

(Confirms Ponti et al. 2018b)

*I think after you play with it for a long time, **you get a sense of what looks good.*** (P3, Foldit, Expert)

*[Working with difficult data involves] **knowing how a cell is supposed to look.*** (P13, Eyewire, Intermediate)



Missing Open Communication

Gatekeeping; low knowledge self-efficacy; lack of adequate community content

Lack of strong communication

***Tension between open science and secret competition**



- ✗ Because learning is social and exploratory, players **need good community content**

-

Gatekeeping from developers

*I've thought about reorganizing the Eterna wiki. ... Probably wouldn't be accepted... **I've seen a lot of other players spend a lot of time creating content and tutorials and organizing things, and it just gets ignored.** [Interviewer: Does it get ignored by the players or the developers or both?] The developers. (P16, Eterna, Intermediate)*

Missing Open Communication

Really, a lack of strong communication

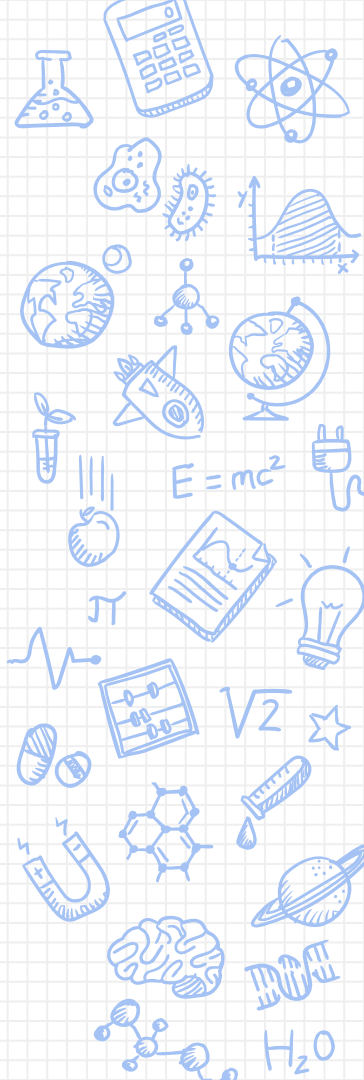
They're using scientific jargon that we don't understand... *Players have to ask a lot of questions, because it's unclear to us. ... I don't know if ... it's just not occurring to other people ... or they're embarrassed and don't want to look stupid, but ... and even I ...*
hesitate to ask any more questions because, like, I'm worried, it's making me look uninformed... (P16, Eterna, Intermediate)



Missing Open Communication

No seriously, a huge lack of strong communication

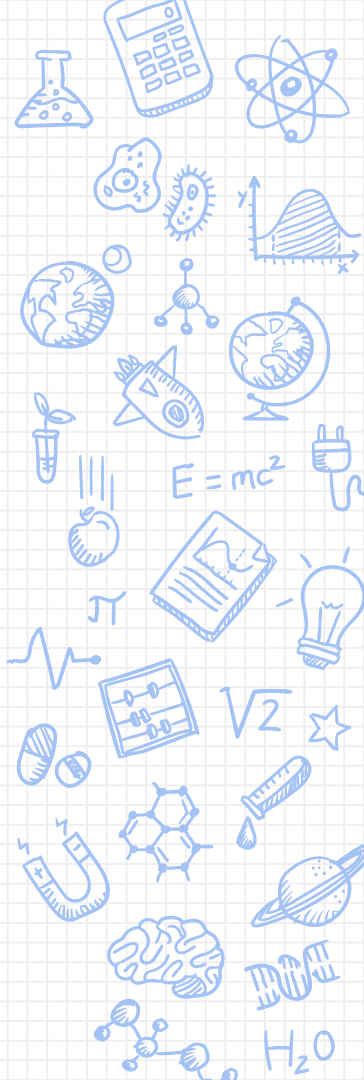
*I'm very iffy on what it means to create a solution
in Foldit and then somehow that goes into the lab...
I still don't really know much about how that happens.
(P11, Foldit, Intermediate)*



Missing Open Communication

Okay last slide on poor communication

*We never, we don't see hardly any results of this development... They occasionally will come out once or twice a year and say we mapped this neuron and show a picture or a collection of neurons. But **nobody's** really saying what actually they are learning from it or what they are trying to learn from it. (P13, Eyewire, Intermediate)*



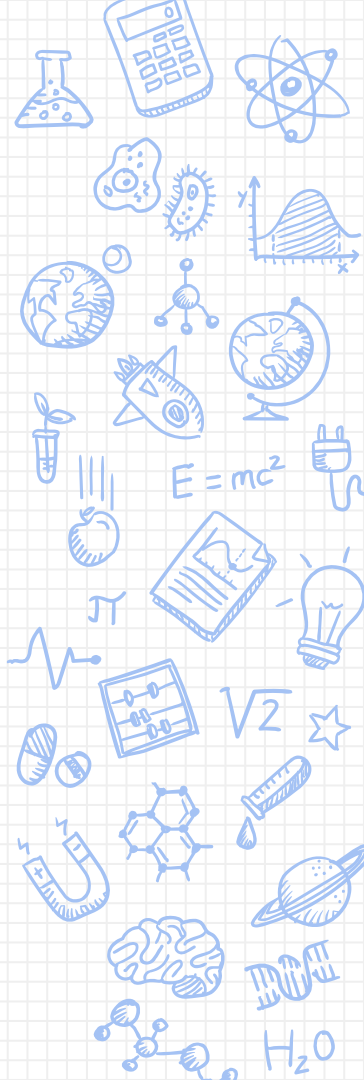
Missing Open Communication

Tension between open science and secret competition



(Confirms Ponti et al. 2018a)

*I'm a new player. I would benefit greatly from new solutions, but I don't have access because I might compete with this player.... **There is some level of weird sort of friction that's like, I can't receive help from you because you're on the other group...** There's such a level of secrecy placed on sharing solutions that it's completely unwarranted. (P8, Foldit, Novice)*



Missing Polish

UI issues

*I just found that I was **fighting the UI** a lot... (P12, Foldit, Intermediate)*

***One of the hardest things to learn is how to manipulate** and see the part of the cell that you're interested in. And to figure out the correlation between the 2D view and 3D view. (P13, Eyewire, Intermediate)*



*You know, when somebody says, oh, I just did this and it came out like that and then **I try it and**, you know, **four hours later and I'm still not getting a result. It's very frustrating. And I have a good machine.** (P3, Foldit, Expert)*

Missing Instruction

Entry skill barrier

*You had no advice ... just “Go for it. Build a protein.”
And I didn’t know where to start...* (P10, Foldit,
Intermediate)

*[The tutorials] are pretty [pause] light. They don’t... go
into any great detail. **They pretty much show you
what the basic controls do, and then throw you in
the deep end.*** (P13, Eyewire, Intermediate)



(Confirms Eveleigh et al. 2014)

I'm frustrated by how slow science is...To hear any results... (P9, Foldit, Expert)

Missing the big picture

When I started ...I just saw a score, but **I didn't know what the score was...** (P10, Foldit, Intermediate)

*I'm not sure how this simulation relates to actually putting stuff in a jar and adding whatever. ... **it seems very far away from the game.** (P5, Foldit, Novice)*

Doesn't teach everything

Most of the skills that you actually use... the harder skills are not even attempted to be taught. (P13, Eyewire, Intermediate)

*So the initial tutorial to learn basic skills to get access to the labs is quite good, but after that, **once you're in the labs there are no more tutorials.** (P16, Eterna, Intermediate)*

Experts struggle to explain expertise

Open Topics

The role of science

Mixed responses:

- ✗ Learning the science happens naturally
- ✗ Not needed to play but needed to be good
- ✗ Needed but not taught
- ✗ Not wanted, “just give me a game to play”

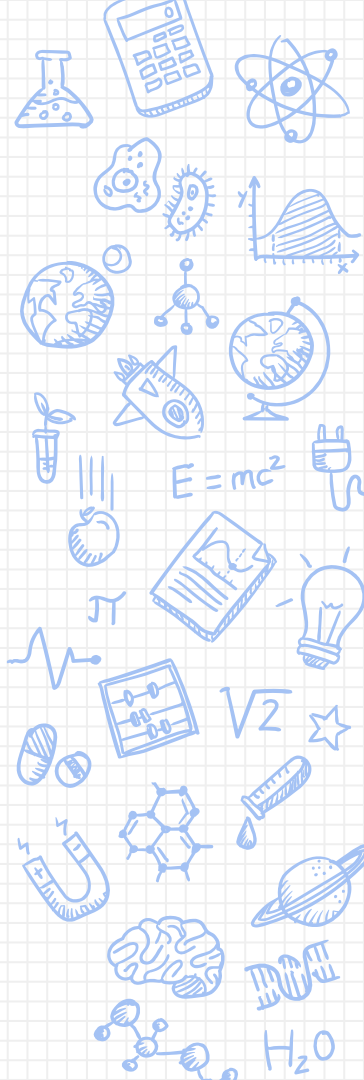


Open Topics

The role of science

One result was clear: **players need a bridge to the scientists.**

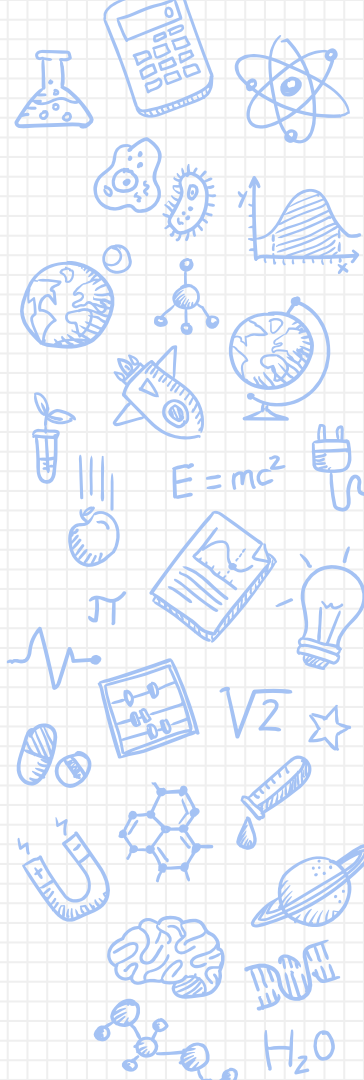
[This player] is invaluable because he is a player and he understands the player perspective, but he also understands a lot of the science, and the scientists, and how they think. (P16, Eterna, Intermediate)

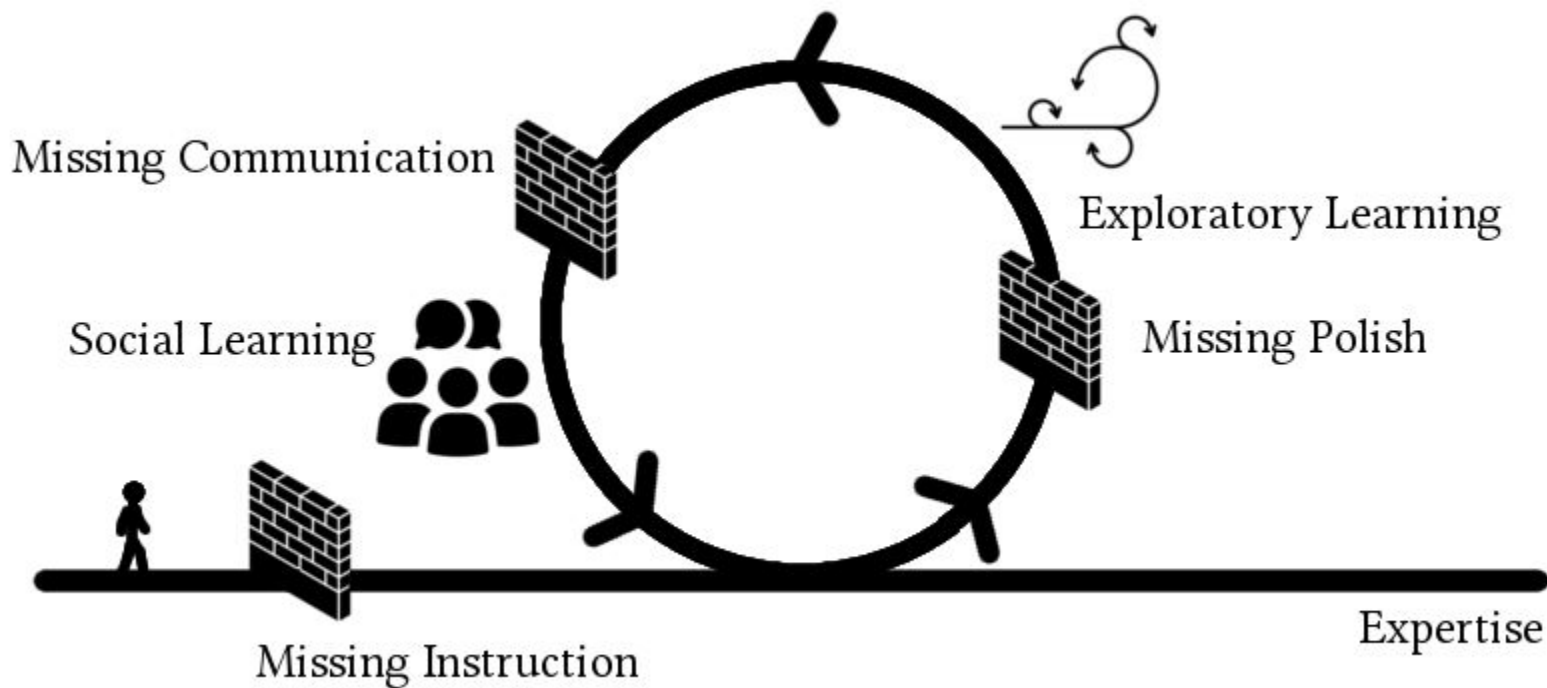


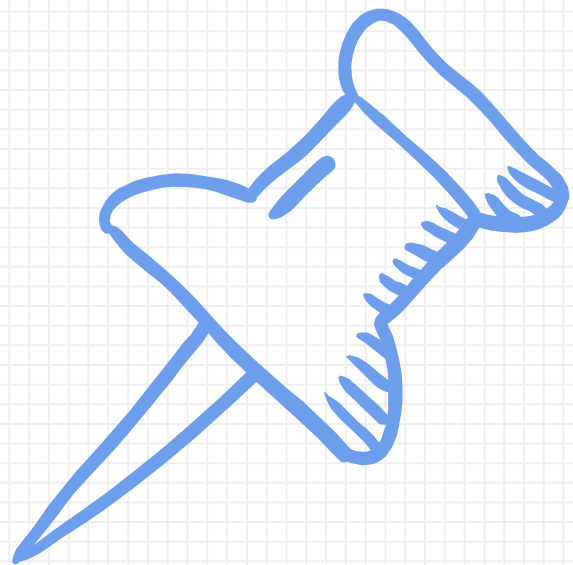
Open Topics

Experts struggle to explain expertise

*Because even I can't really put into words what makes a well-designed protein. Like you see a lot of good proteins, but **it's really hard to put into words.** (P12, Foldit, Intermediate)*







Takeaways

Add or improve social features for connecting players

Collaborate with professional community managers

Add or improve social features for connecting players

Exploratory Learning

Encourage exploration and intelligent trial-and-error

Path to Expertise

Social Learning

Add or improve social features for connecting players

Collaborate with professional community managers

Exploratory Learning

Encourage exploration and intelligent trial-and-error

Multiple Motivators

Enable science, entertainment, and learning



Missing Open Communication

Lack of Community Content

Address, discourage, and prevent gatekeeping.

Provide technical and social assistance for community content creation.



Provide technical and social assistance for community content creation.

Provide more science details and praise specific contributions.

Collaborate with communicators and science journalists.

Missing Polish

UI Issues

Collaborate with professional UI/UX designers.



Collaborate with professional UI/UX designers.

Collaborate with professional software developers.

Collaborate with professional UI/UX designers.

Collaborate with professional software developers.

Collaborate with professional game designers.

Missing Instruction

Entry Skill Barrier

Collaborate with professional instructional designers.



Missing Instruction

Entry Skill Barrier

Collaborate with professional instructional designers.

Lack of Adequate Feedback

Establish qualitative P2P feedback and automated in-game feedback mechanics; provide regular science communications.



Collaborate with professional instructional designers.

Establish qualitative P2P feedback and automated in-game feedback mechanics; provide regular science communications.

Teach the core loop and contribution framework early.

Collaborate with professional instructional designers.

Establish qualitative P2P feedback and automated in-game feedback mechanics; provide regular science communications.

Teach the core loop and contribution framework early.

Collaborate with expert players.

It Takes a Village

- Scientists
- Community managers
- Communicators
- Science journalists
- UI/UX designers
- Software developers
- Game designers
- Instructional designers
- Expert players



Funding Matters

Current funding:

- Research / Government Grants

Consider:

- Entrepreneurial partners (startups, incubators)
- *Pro bono* collaborations with professionals



-

Thanks



Northeastern University
**Khoury College of
Computer Sciences**

Co-Authors

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Britton Horn

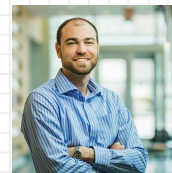
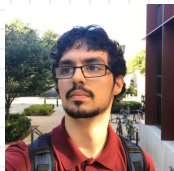
Matthew Guthrie

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Special Thanks

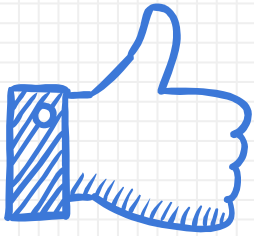
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THANKS!

Any questions?

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You can also split your content

White

Is the color of milk and fresh snow, the color produced by the combination of all the colors of the visible spectrum.

Black

Is the color of coal, ebony, and of outer space. It is the darkest color, the result of the absence of or complete absorption of light.





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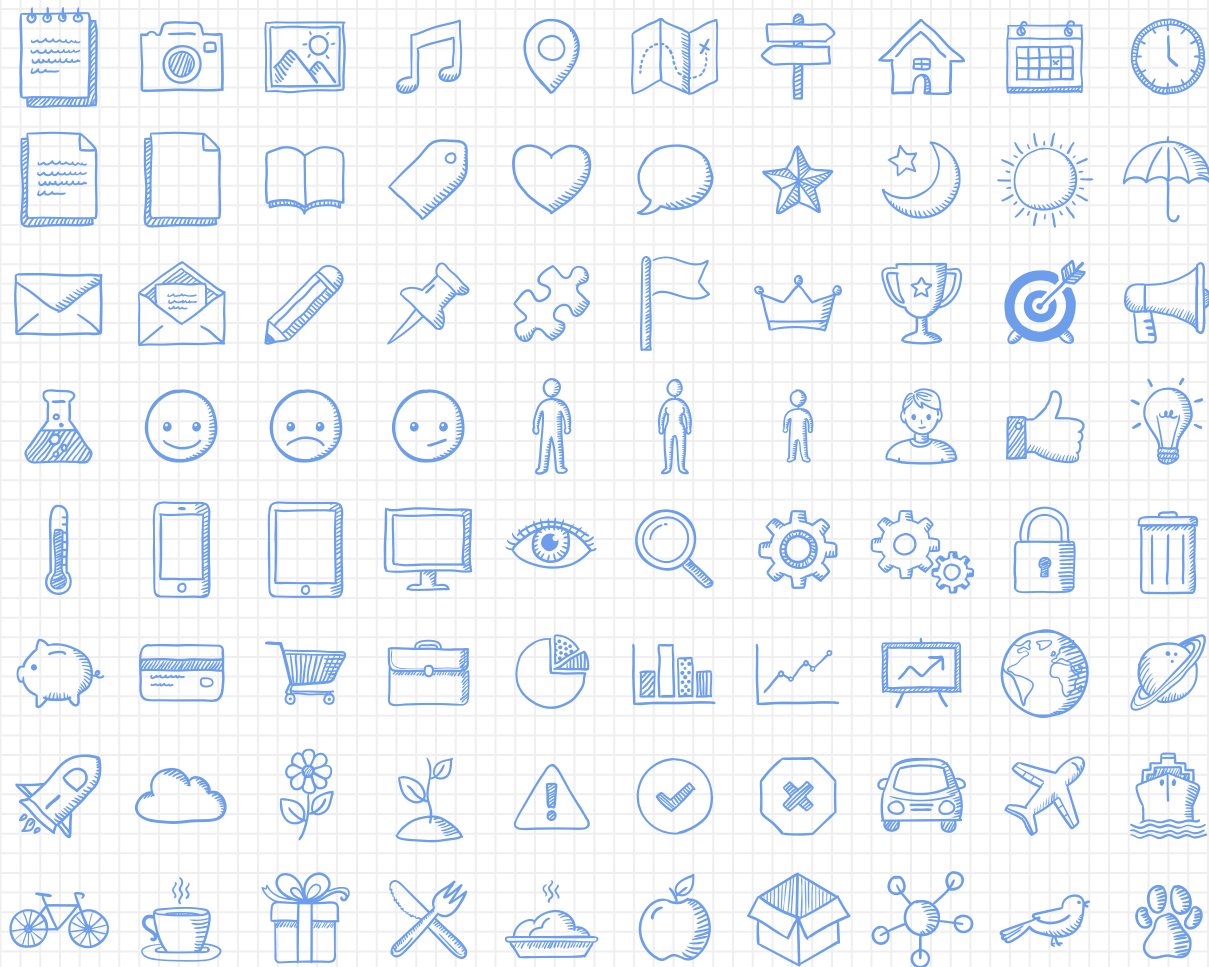
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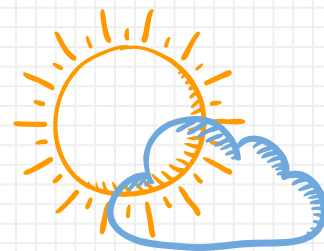
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