22-11-2021 Graduation Report

Sketching with Tangibility

An intuitive approach to design products based on *flexibility*

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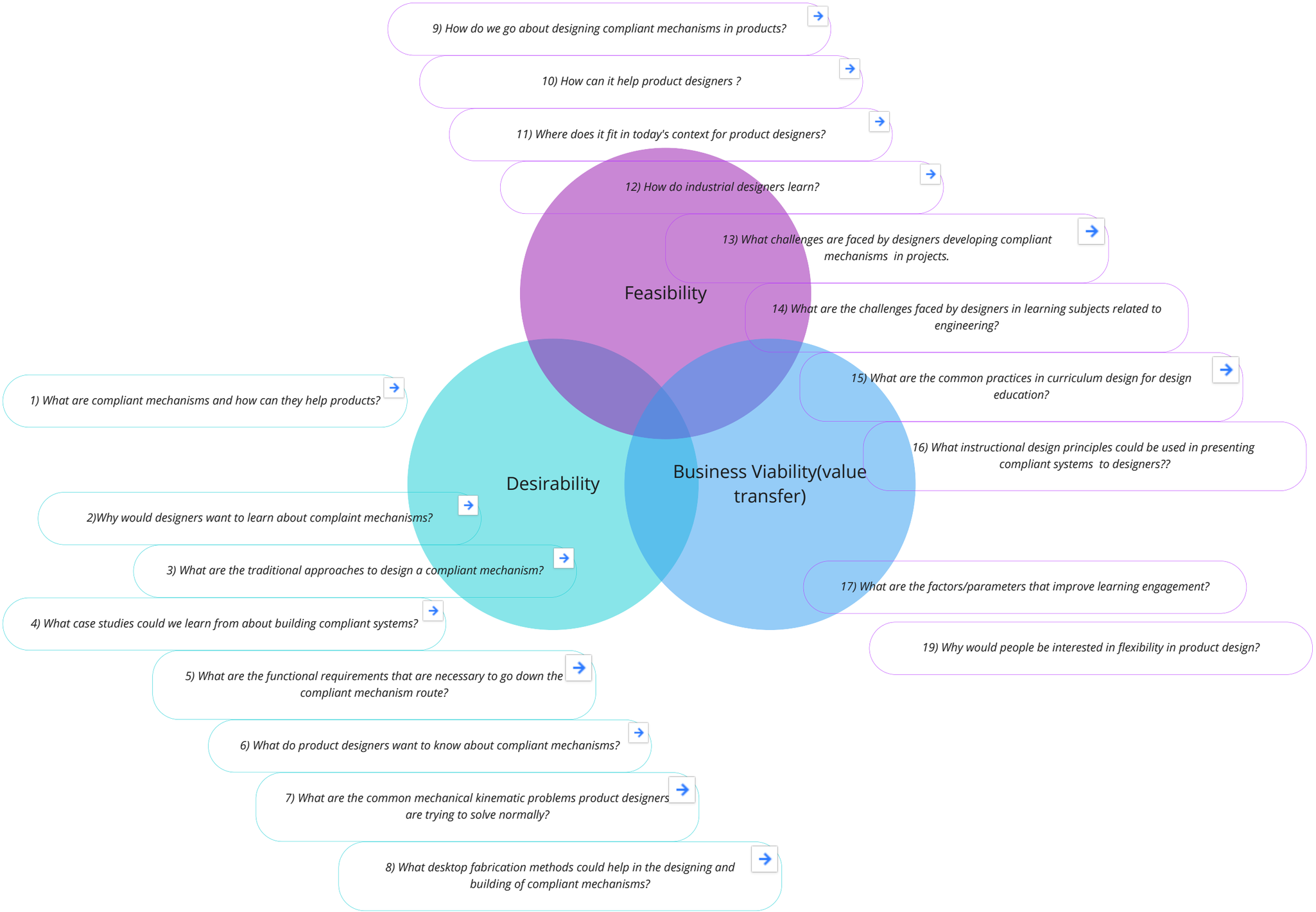
Contents

Appendix A : Research Map



Appendix B - Interviews

Date: May 27th 2021
Time: 10am CET
Method: Teams meeting
Name: Paul
Title: CEO, product manager of a Design studio
Topic : Use of compliant mechanisms in product design.

Questions :

1) What challenges do you face while developing mechanisms.

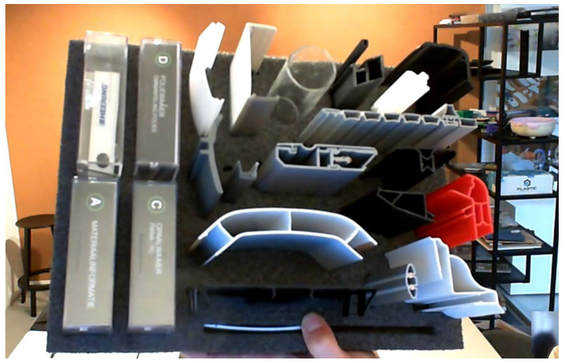
Develop,Integrate, Human interaction

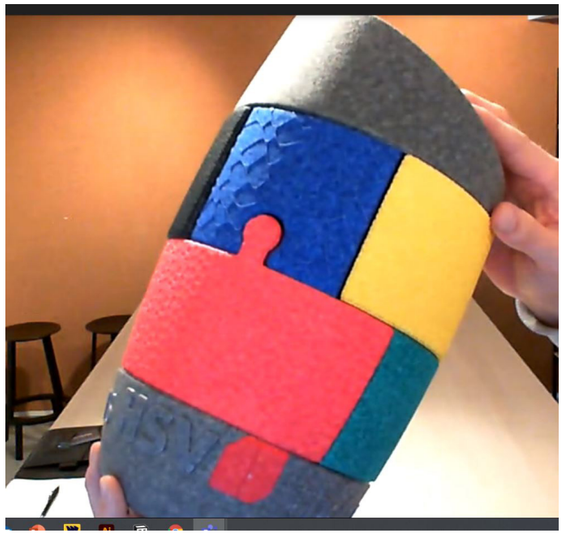
2) What is the average developmental time for prototyping a mechanism?

Not a good question, it depends on the complexity of the project. We mostly work on bottles and cars. We are in favour of using product/mechanisms already available instead of developing things from scratch. Examples of challenges we are normally given are : simpler locking mechanisms, these mechanisms could be interchanged to function for different products different scales.

3) Do you have a workflow? Could you walk me through the work flow for develloping mmechanisms?

Very good brief of functions - Integrate cost price(get an estimate to develop for the client to make decisions - Look at if the product would involve moulding costs and other developmental costs - In case of developing mechanisms we look at all kinds of existing solutions from different markets(sort of tech mapping) - Identify mechanisms that would come close to what we





need to achieve - we then go to the client with ideas of what we've found i.e technology - get an idea of what they think of what we've discovered or come up with - once we have discussed with them and filter down techniques then we make a morphological map - then we zoom in on such mechanisms - the morphological map is an input for a team brainstorm - In the brainstorm we would see what is interesting then we would order such parts that interests us to study them - there are a huge number of companies that produce standard mechanisms - we have a lot of books full of mechanisms and hinges - There are a lot of third party suppliers which supply only mechanisms -

Short form : -Briefing, cost price, investment opportunuties, existing solutions, make overview of existing products, discuss with client, morphological map input for team brainstorm, order parts and study them, huge number of companies, books, libraries of mechanisms, Onkenhout, no body is doing this for compiant mechanisms, check out Onkenhout, one inspires the other, technical lego blocks, combination of product design, no incentives for production companies, no incentives.

4) What is your understanding of compliant mechanisms? why is it that it's not prevalently used inspite of it's pros?

the opportunity for compliant mechanism is that no body is doing this for compliant mechanisms - further iterations happen with sketching - making mock up models - we also use technical Lego to make preliminary mock ups - then we try to integrate into the product design then we start testing it and prototyping - Now when you talk about compliant mechanisms, it does not come out of the top of head - Compliant mechanisms would most necessarily be needed to be injection moulded - Proto mould uses a cube to demonstrate what they could do with injection moulding for marketing purposes - There is no sudden incentives for injection moulding companies to market or educate the customer i.e us in this case to deal with compliant mechanisms - They can't make money from it - There is no business incentive behind using compliant mechanisms and that is why it is less well known - There is great support behind rigid body mechanisms - For compliant mechanisms we don't have anything.

5) Do you think having a better knowldge into developing compliant mechanisms help you in the earlier prototyping phase? How would it help?

We have a ton of sample boxes for various materials, mechanisms etc. If we would have some sort of sample or examples in developing products i.e wrt use case then it could really help us in the initial prototyping stages. We don't have anything to look at for inspiration to lean about complain mechanisms. If we do have something like that then we would have a way to incorporate it into our designs. Here are some examples of samples that we store for further reference during the product development.

6) Would you have problem scenarios cases I could work with latter on in the course of this project?
Yes, I'll send you a few cases in some time.

Key Take Aways :

1.Developing mechanisms is something that is done with the help 3rd party suppliers.
2) Product design agencies normally depend on libraries and mock up demonstrators of mechanisms given to them by 3rd party suppliers.
3) The workflow for a job is as follows : write a good brief which includes cost estimation, then look at products that already exist with product features we'd like to implement, identify mechanisms or features that come close to what is expected from the design(tech mapping), inform the client, make a morphological chart with mechanisms, use the morphological chart in a team brainstorm, order parts to study them further and then go into making things with legos and building up from there.
4) The opportunity for compliant mechanisms is that no one is selling these mechanisms like the 3rd party companies such as Onkenhout. Normally if it is developed it comes under the IP of the product.
5) We as product designers don't have compliant mechanisms from on top of our head. It's not something we know of.
6) In the early prototyping phases what helps us is sample boxes, demonstrators. We don't really have anything when it comes to complaint mechanisms. (Examples of samples from companies shown in the images).

Locking Mechanisms/ Different Scales/sizes

Flexibility and part integration

Transferring loads

Reducing complexity in assembly of parts

Key Take Aways :

1) From the cases onboarded from the product design companies we are able to group them into 4 categories.
2) The categories are Locking mechanisms, load transfer, flexibility and part integration, reducing complexity in assembly of parts.

Date: May 27th 2021
Time: 2 pm CET
Method: Teams meeting
Name: Jeroen
Title: Product Engineer at a prominent design studio
Topic : Use of compliant mechanisms in product design.

Questions :

1) What challenges do you face while developing mechanisms.

We mostly use living hinges for bottles, and bi-stable mechanism to open and close the bottle cap, sometimes we use compliant mechanism in cases where the rotation point is outside the product. The design work we do is not so much with mechanisms but more so with plastic parts, housings, framings, casings etc.

We do use regular mechanisms in products, with compliant mech, it's so much to with not knowing how to work with it. We do depend on suppliers for mechanisms it's not always developed in house.

3) Do you have a workflow? Could you walk me through the work flow for developing mechanisms?

Mostly our clients do the internal mechanisms of the machines and we do the outside mostly making it look good and seamless. Product perception is something we always work on i.e CMF. Focus is mostly on producing high quality stuff. But for myself I like to try things out and see what we could do with it, I print out parts etc.

4) What is your understanding of compliant mechanisms? why is it that it's not prevalently used in spite of it's pros?

Product designers limit themselves to work with new things because they don't feel safe using it in their day to day work.

Not knowing is not using, if you do have a database of compliant mechanisms and how they work and how they are modelled then it would help us out when designing. Another point is that we could use this in multi material designs in injection moulding for example.

Key Take aways :
1) Most common compliant mechanical element we use is the living hinges because we do a lot of work with bottles.
2) In the design work,. we don't really build a lot of mechanisms but we work on the CMF(colour material finish)
3) Dependance on suppliers is high for mechanisms.
4) OEMs(who are their clients) are mostly responsible for the internal functioning of the product.
5) As a product designer I like to tinker around with things, try out new stuff.
6) Not knowing is not using so if we do have a way to approach complaint mechanisms we coudl try it out

Date: June 7th 2021
Time: 3 pm CET
Method: Zoom meeting
Name: Patty
Title: Biomedical Graduate student
Topic : Challenges faced by product developers while developing products incorporating compliant mechanisms.

Questions :

1) How did you go about implementing compliant mechanism in your project i.e the symbihand?

The starting point was a PhD thesis that was done and following recommendations given in the thesis. I did not use any particular methodology. The ideas for features I used in my project are quite common in bending elements.

2) Did the feature work well?
The flexibility of the element was less in order to reach the final position. It broke very easily, the endurance was way too low for repeating tasks. There are different parameters that determine the properties of the element such as the shape, the thickness, profile, material properties, normally shape optimization is used to determine the structure and I think that is the way to go but I made three versions of it and compared it and chose for the best option. I did some FEM analysis in solidworks. The drawback with the optimisation tools is that it's mostly for static structures. The problem here was that it's not static but a dynamic situation.

3) What were the other challenges in developing compliant mechanism in your product?
The key challenge is finding the right balance between the amount of stretch that is needed for allowing the range of motion, to find the right amount of tension in the compliant element to maintain a structure while being flexible at the same time. Optimization is key here for it to be fully functional.

The other challenge basically was that I didn't really know how to approach the problem very well.

4) What was the reason you chose for compliant mechanism instead of the conventional rigid body method?
The main reason was to maintain a functional form. I didn't want things to be pointy and not very comfortable for the person using it. It must be safe for the users and that's why one of the main functional requirments was for it to be conforming to the skin of the user.

5) What could have helped you with compliant mechanisms in your project?
A method in which you could see that these are the elements commonly used to achieve this intentended effect could be of help, so you know where to begin. A method in approaching the design of compliant mechanisms could also have helped. The challenge is that there are so many parameters in this, it is dauntiing as to understanding what is your start point in the design that you are trying to achieve. Some sort of a method and strucctuure could already help.

6) What was the manufacturing methhod used?
I stuck with 3D printing for compliant elements mostly and intgrated it with rigid body elements for the hydraulic system. I wanted it to be made out of one material because then we wouldn't have had to make use of a lot of manufacturing processes.

7) What was your workflow in developing your product?
I used what was availablee in literature and made three different versions of the structure and compared it then I did some FEM analysis, none of the structures really worked out for me. I did not know how to approach iit from ground up.

8) What was the material used?
All of it was made from Nylon from a company called oceans. The properties it had was promising.

Key Take aways :
1) No particualr methodology used in developing the complaint feature in the product.

2)Feature developed from a common elements library or library of features.

3) The parameters influencing the compliant element are shape, the thickness, profile, material properties.

4) The complexity is in the approximation of dynamic forces for optimization is a barrier in calculating, it needs to be prototyped and tested mostly.

5) The reason compliant mech was used was because of proximity with the human skin and so rigid parts that hurt the skin wasn't a way to move forward.

6) A method or approach to find a start point to the compliant mechanism could be of tremendous help in the course of the project.

7) An understanding of basic parameters for the design could have helped me in getting to the starting point of a design(minimally viable concept).

8) 3D printing was the preferred method used for prototyping as it integrates the whole product in one material.

9) Material used was Nylon, it's flexibility was promising.

Date: June 8th 2021
Time: 6 pm CET
Method: Zoom meeting
Name: John
Title: Product Designer
Topic : Use of compliant mechanisms in product design.

Questions :

1) Have you ever had to use compliant mechanisms in any of your projects?

I don't know if I've ever used compliant mechanisms in my projects, although I've done tests for 3D printed eye wear those were lliving hinges.

2) What do you think of when you hear compliant mechanism?
To be honest I didn't even know what a compliant mechanism was until when you told me about it. Although I know it only now, I know it only through the wikipoedia definition.

3) Do you see a potential for thiss in industrial design as a professor?
Ofcourse, but I think it's going to be a material issue though. Like any material with moving parts, there are a number of cycles it could endure.
I don't know if the number of cycles could be matched between the normal rigidd body mechnism and a compliant mechanism. I think it would break quite easily, It might be good for less expensive parts that are semi dispposable or limited in their use. As a designer I'm not going to think, how am I going to use compliant mechanism in my project, I'm going to be thinking " how do I make this thing move?" and may be one of those ways could be a compliant mechanism.

4) What are the parameters that you think are important and that you would consider while developing a mechanism?
Firstly, the functional constraints. How many cycles is this product supposed to last. Is it 10 or a 100 thousand? Secondly the force that it would endure. On the more experiential side, how do you think the user would want to feel while using this mechanism? Is he satisfied? Is it pleasurable? Is it enjoyable? Does it make them feel better about using the object? So this depends on the brands value and the customer's needs and preferences.

5) Thinking about mechaisms in products in general, I think of a few features eg : Locking, openings, switches, do you think of something else?
Check out Lucas's work on physical UIs? You could probably build a few things that he's developed using compliant mechanisms. He made these renderings of physical UIs, the whole point of a button or a knob or anything else is it's tactility which is completely missing from this experiment. So may be if you say hey, why don't we build a couple of these things and try a couple of different iterations on the actual mechanical properties and how they feel, try a bunch of different feelings for each of these, may that would get him interested in talking to you.

6) **One last thought about designing any mechanisms really-**
In one of my experiences in developing the protos eyewear, the most important thing was the hinges. If the mechanical touch points in the product doesnt feel quality then people aren't going to believe that it is a frame that is worth 500dollars. It's tricky because it's very subjective, the way you interact with the object is informed by all of these mechanisms and it tells you a lot about the products quality. How do mechanisms relate to the percieved quality of the device?

Key Takeaways :

1) Living hinges is something that I've used a quite a few times for wearable projects.
2) I didn't know what a complaint mechanism was until you told me about it.
3) As a product designer John was apprehensive about the number of cycles a product designed with thiss approacch could withstand.
4) As a product designer, the most important question is how do I get this thing to move?
5) As product designers our first and foremost impportant thing is functional constraints. Secondlythe question is what are the input and output loads? Third is the user expperience, how does the user feel using this particular mechanism?
6) A products physical tactility coould be explored through compliant mechanism approach.
7) The perception of quality is another concern materials and compliant mechanisms.

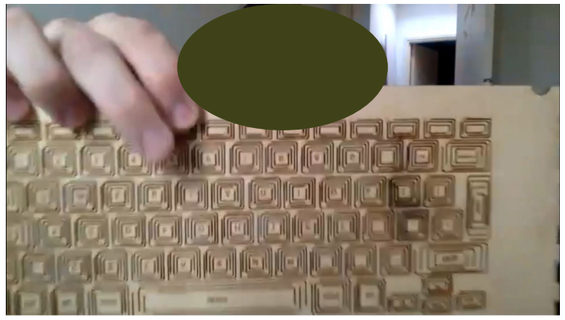
Date: June 26th 2021
Time: 10 am CET
Method: Zoom meeting
Name: Johan
Title: Product Engineer
Topic : Use of compliant mechanisms and producibility

Questions :

1) What kind of functional requirement would warrant the use of compliant mechanisms?
According to the design for manufacture theory, it states that if you're dealing with movement then we could have more number of parts but compliant mechanism is just the opposite, it's about integration of parts. Reduction of parts could be a requirement but it's not a functional requirement but a manufacturing requirement. Which means faster assembly processes, reduction of cost, I think it's about the added value than the functional requirement. The key question to be asked is, what is the added value to the product or system.

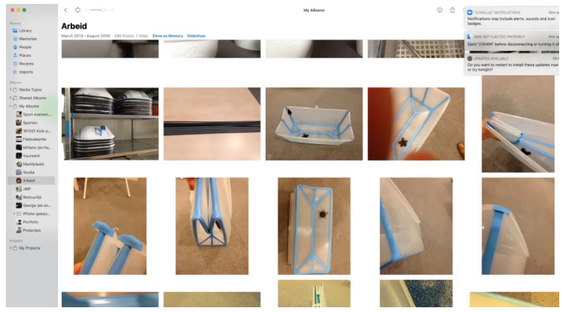
2) How did you go about material selection in compliant mech projects?
To be honest we did not do a lot of material testing.

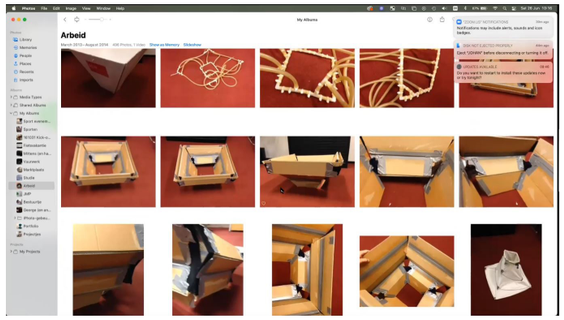
3) What were the constraints you were working with while designing compliant mechanisms?
Firstly it was the space constraint, then degrees of freedom and other requirements such as should be able to be fixed with some other part(part integration).



4) How easily could compliant mechanims be demonstrated to industrial designers?
First of all there must be an understanding of the rigid body elements and the flexure elements. These basic principles would already trigger stuff in their heads. Don't start with the complicated NASA stuff, keep it simple then make it complex. Principles are important. So the most important things are constraints such as identifying thee fixed and flexural parts(parrt configuration).First step is to understanding the configuration and achieving the movement then the second step would be to understand the other parameters such as thickness and length, material etc.
All of this comes down to the relative difference of material between the rigid and material part. Also fatigue is something that needs to be addressed. You could also show them compliance that could be achieved through different materials eg the kids bath(Fig xx). For a quick understanding of movement, simulations help a lot but prototyping works best.

5) In the place of your work i.e a factory what is he scope of compliant mechanisms that you saw?
For the problem case I was looking at simple living hinges, part integration of a locking mechanism. I want to get rid of alll the spriings. So part integration and assembly. Also cost effective and saves time. So when you look at quality time and cost, it plays out very well. Look at Porter's value chain as to how value could be added in organizations.





Key Takeaways :

1) Compliant mechanisms in terms of producibility it mostly helps with integration of parts, these are not the functional requirements but additional requirements. It has a domino effect on other aspects such as the manufacturing processes, cost of production because of it's impact on assembly of parts.
2) The most important constraints we were working with at the time were space constraints, degrees of freedom and the need for part integration.
3) In order to demonstrate compliant mechanisms to industrial designers, first of all an understanding of rigid body elements and flexure elements must be made. These basic principles already would trigger ideas.
4) Secondly, defining constaints is important. Understand the parameters that would contribute to these constraints. Fatigue is something that needs to be taken into account.
5) The best way to go about making this is to directly delving deep into prototyping.

Date: June 22nd 2021
Time: 9pm CET
Method: Zoom meeting
Name: Erik
Title: Associate Professor and project stakeholder
Topic : Teaching designers and conducting workshops

Questions :

1) Putting together a workshop for designers

What are they learning? Are they learning compliant mechanisms and kirigami or are they learning design in a day? If you want to design the workshop well you must have an answer to that question. You're dealing with people who have no experience with this, and they certainly wouldn't have done all of this in one day. You must consider the ppossibility that they are going to learn more about prototyping than they are going to learn about compliant mechanisms. So this is like a classsic case of headfake where you say that we'll be doing this but in doign this you're learning a totally another thing. This has to be a conscious choice. Eg : The workshop would be about rapid prototyping but what would be taught is compliant mechanisms and kirigami.

2) How to present the topic?

You must be really aware of what you're doing for example how do you teach them all this but maintain a light tone and a fun tone? If there is a disconnect between what you're saying and what people were expecting, then you get a clash.

3) Rule book for design teachers

If you have 30 students, you'd want to give them assignments having some variations but based on the same theme. Put them in groups of 4 or 5 and then in the end you have vaariety in the results achieved during the day. So basically for the workshop specify - generate - analyse - validate.

4) Designing the workshop

The focus must not be on the end result, the focus should be on the learning and the experience.

5) Resources for lasercutting

Go and seek some kind of partnership with bucky lab.

6) About the IDE workshop from feedback

Students like the mix of active and passive activities. May be it's a good idea to have a video to set the stage for them. Showing them that is something that is interesting. May be have a commentary on videos, curate a list of videos to watch before the workshop. What could they do in their downtime?

Key Takeaways :

1) The main thing while designing workshops is to understand what are we trying to help them gain? Is that in their interest?
2) How are you going to make it understandable to people who are totally uninitiated to this topic?The answer to this is crucial.
3) As a teacher you must be on top of the topic to make it fun and interesting to your audience.
4) Specify - generate - analyse - validate could be a way to establish the workshop.
5) Focus must be on the process and not on what the results are. It is important to put the learner first.
6) Setting the stage for them is important so they know or have context on what they are dealing with.

Date: June 30th 2021
Time: 1pm CET
Method: Zoom meeting
Name: Stefan
Title: Lecturer
Topic : Teaching engineering to designers

Questions :

1) How is curriculum designed for designers and what considerations do you take while designing it?
Learning goals are written down mostly in a broad sense to keep it more flexible. An example of learning goals could be " Students are able to model and predict behaviour of compliant systems following an experiential approach".
For complian mechanisms what would be involved is Rapid Prototyping, Materials and modelling, and Material science. The key is to understand how are we going to frame it for designers? In mechanism design we have a beginning and the end, it's important to understand how different is it going to be for compliant mechanism.

2) Difference between a mechnical engineer and a design engineer
Given an instance, a mechanical engineer would be able to tell these are the set of solutions that could solve this and be able to first appproximate this through caalculation then validate it through simulation before going into making it. For designers we moostly valiate it by making prototypes. As a mechanical engineer you are not concerned with the irrationality of human beings, pour focus is on user centerdness. The decisions are made via logic / didaction principle in mechanical engineering, in designing the approach is veery much more iterative. The situation for designers are so varied that only some number of decisions could be made via logic, everythiing else is experiential.

3) How do designers learn?
I recently came about this interesting thing called productive failure. The thing is failure is difficullt and people don't want to go through it. Once a person comes out of a failure, he has learnt a lot. When teaching teachers say you'd need to fail but not often d they want to fail themselves. Here's an interesting debate. Should we teach first then try or try first and then teach? Learning by doing always works. For design, understandding what you're working with takes more than just reading. In the case of a workshop, you're dealing with people who are super interested. So **produtive failure** would be an interesting **pedagogical approach.** So what is important for the workshop is to understand both our pedagogical and didactical approach. Pedagogy is how people learn and didactics are the exercises that we would give them. At the same time it is important to approach problems in a structured manner. So they would need a guideline or a methodology not to religiously follow them but to give them an initial pathway.

4) How to go about designing learning experiences?
Kolbe's learning cycle is the best way, it's also the way we function in the design world. So basically designers learn by firstly thinking about the design, then making the design, testing the design, improve the design. That's basically the design cycle.

5) What are the challenges you face while transferring engineering knowledge to designers?
The callenge is in going from the abstract to the real world. The absract is the calculations and the real world is the implementation. Some students they tell you, see the calculations are correct but the result is just not what we predicted! A good designer is informed about the abstract calculations to make a sensible real world design.

Key Takeaways :
1) The main thing for designing a curricullum are the learning goals. It is important to understand the main topics what would be covered and how these topics must be framed and presented to design students.
2) The difference between a mechanical engineer and a designer is that the designer is user focussed. Designers make their decisions more experientlially i.e by building and doing.
3) Productive failure would be a good pedagogical approach for designers. The first step with productive failure is to give the learners a challenging task so that they can fail and then instructions are given to them.
4) A step by step approach is also required if we do have a time constraint to be aware of.
5) The challenge in transferring engineering knowledge is always in going from the abstract into the real world scenario.
6) A good designer is able to have a good estimate of the abstract to transfer it into the real world.

Date: August 12th 2021
Method: Email, LinkedIn
Name: Reinier
Title: Industry professional and educator
Topic : Compliant Mechanisms and teaching compliant mechanisms

1) What is the definition of compliant mechanism you refer to when you have to explain it to a person with no idea of it at all!?

Compliant mechanisms are mechanical devices which get their function from the deformation of slender segments. They work by bending and I also like to call them flexible mechanisms. This is in contrast to conventional rigid body mechanisms, which get their function from the relative motion between rigid links connected by lower kinematic pairs, e.g. hinges. As such, compliant mechanisms can be made without this relative motion between components, which eliminates wear, need for lubrication, the need for assembly, reduces part count up to a fully monolithic architecture. As such they are very suitable for miniaturization (e.g. MEMS), clean applications such as medical tools and clean room applications and for example vacuum applications (no cold welding between relative components). However, because force and displacement is coupled they are more difficult to design compare to rigid body mechanism where displacement and force can be treated separately.

2) How did you get started with this and what excites you about it?

I have been introduced to compliant mechanism when I started my PhD. I have a robotics background and was always fascinated by the fundamental components of machines; mechanisms. I had worked mostly on the analysis and synthesis of rigid body mechanisms and was invited to do a PhD at precision and microsystems engineering related to flexible mechanisms. What I find fascinating about flexible mechanisms is that a very integral design approach is possible. That means that all functionality can be incorporated into a single component. In that sense they are much more close to the mechanics we find in nature, which hardly ever uses rigid body mechanisms. In nature, everything is flexible and organisms form a single component structure in the same way.

Another exciting thing about flexible mechanisms is that they can be made down-scalable. Because a single component architecture does not require any assembly they can be manufactured by 3D printing (e.g. two-photon lithography) or lithography processes (e.g. deep reactive ion etching) in batches and extremely small, much like chips. This enables their application in micro-applications such as sensors and opens up a window to create meta-materials with very unnatural properties when unit-mechanisms are tessellated into a larger lattice.

What excites me most about compliant mechanisms is how creative the design of compliant mechanisms can be. In that sense, the domain of compliant mechanism remains largely unexplored. A monolithic architecture (single piece) allows more complex and organic looking device structures to be more easily created compared to rigid body mechanisms. Somewhat counter intuitively this allows very complicated rigid body mechanisms to be greatly simplified. One example of this is the work done by Flexous mechanism BV, where they redesigned the entire escapement mechanism of mechanical watches to comprise out of only a single component.

3) Do you think designers would benefit from learning about compliant mechanisms? how do you think they would benefit?

Yes I do think designers would benefit from learning about compliant mechanisms. If only for expanding their general knowledge. More specifically I think that understanding compliant mechanisms is a good way of understanding stiffness and flexibility in general. Of course, the design of compliant mechanisms is more of a applicational nature. In that sense I think designers should first and foremost learn about the fundamentals of structural mechanics and material science. From there the step towards compliant mechanisms is relatively small

On the other hand, using only building blocks of compliant mechanisms can be extremely useful for designers, without requiring extensive expert knowledge about their theory, analyses and synthesis. In many design cases such pre-designed building blocks can be readily applied and incorporated into the design. Think of direct replacement of kinematic pairs with their flexible equivalent (e.g. revolute, prismatic, cylindrical joints).

Besides design for function compliant mechanisms have the capability for cheaper design (reduced part count, think of your shampoo bottle cap), which means it can be an important tool to make mass produced products affordable.

4) Do you think the power of compliant mechanisms are utilized now? How do you think it could be harnessed better?

To my knowledge compliant mechanisms are mostly used in applications that require precise and repeatable motion, microelectromechanical systems (MEMS such as accelerometers) and mass produced products

I do believe there is way more room for their application. For example, currently, metamaterials are mostly an academic endeavor, but as soon as 3D microfabrication gets more mature and faster (so we can produce large volume) we will find more and more actual architectured materials in practical applications. Think of materials that can absorb huge amounts of energy on impact, materials that can learn and adapt to changing circumstance, materials that can be programmed and can do mechanical computations internally without the need for explicit electronic devices. Also, cheaply produced devices may make technology normally reserved only for the rich available for the less fortunate, e.g. medical tools.

5) If you were to teach designers about compliant mechanisms how would you go about doing it in the simplest way possible?

When I did some teaching during my PhD I always took a very practical and hands on approach. You cannot really learn an intuitive sense for compliant mechanism from books and computer simulations/calculations. You have to actually feel the devices, you have to interact with them, play with them in order to truly understand their behavior. Then it becomes possible to internally visualize how compliant mechanism will behave and this enable of course a large amount of creativity.

I did so by creating lego building kits for compliant mechanisms. This allowed me to create many demonstrators that could go round in the lecture hall. Also, we organized hands on sessions where people could experiment and play with these kits to test and verify their design hypotheses. This will give very direct feedback on what works and does not

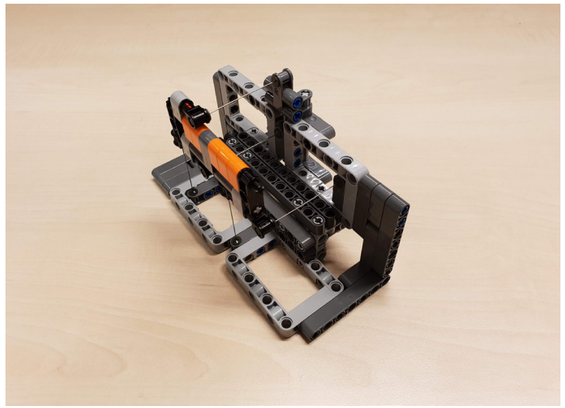
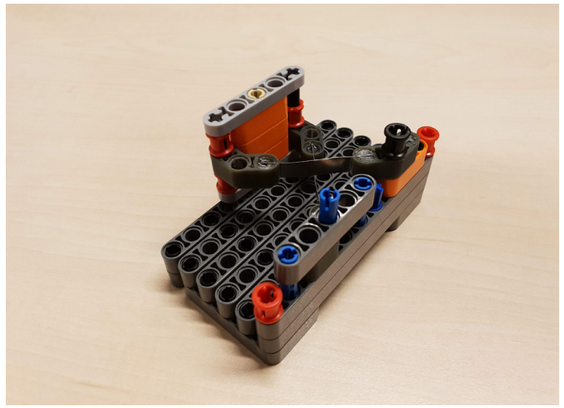
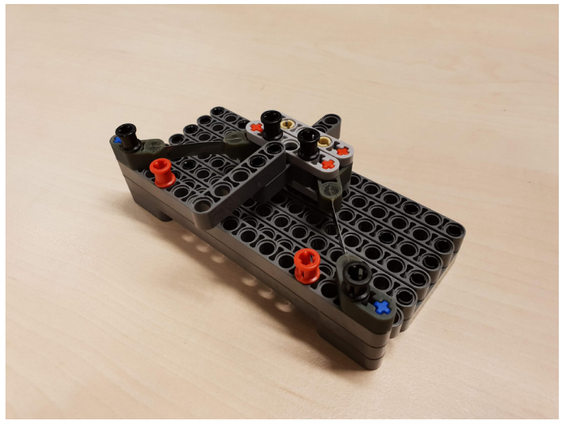
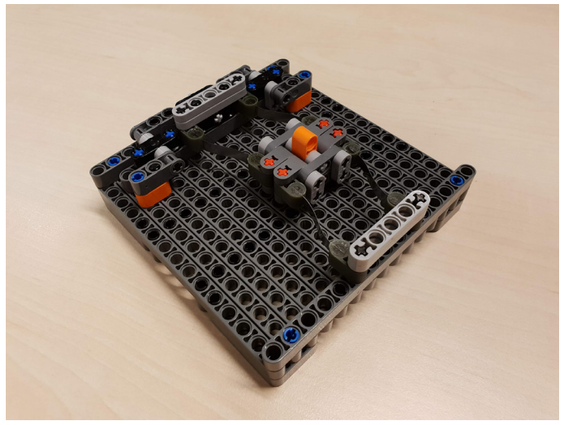
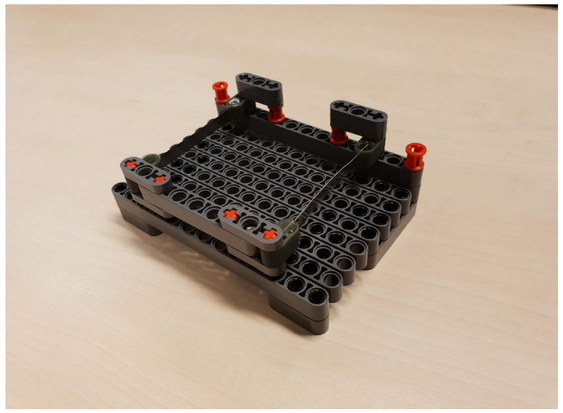
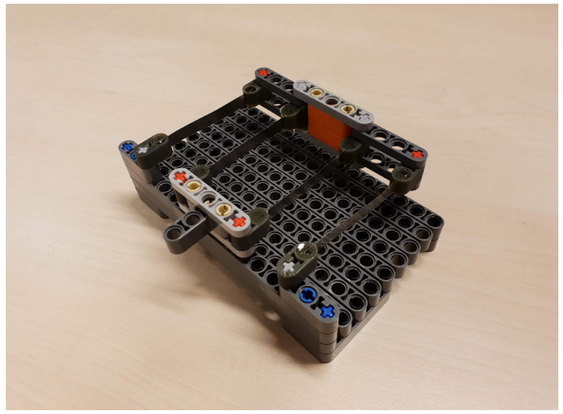
From a more theoretical perspective it is always a good idea to have the students understand rigid body mechanisms. Concepts in rigid body

mechanisms translate very well to compliant mechanisms as well. That is for example kinematics and dynamics, degrees of freedom, degrees of constraints, over-constraints, building blocks and so on. Once people have a clear idea of these concepts it is a relatively small step to apply them to compliant mechanisms. Again, demonstrators and many examples will help the students to grasp these concepts quicker than when just provided with theory. Demonstrators also just make it fun and you see theory readily applied in an exciting way.

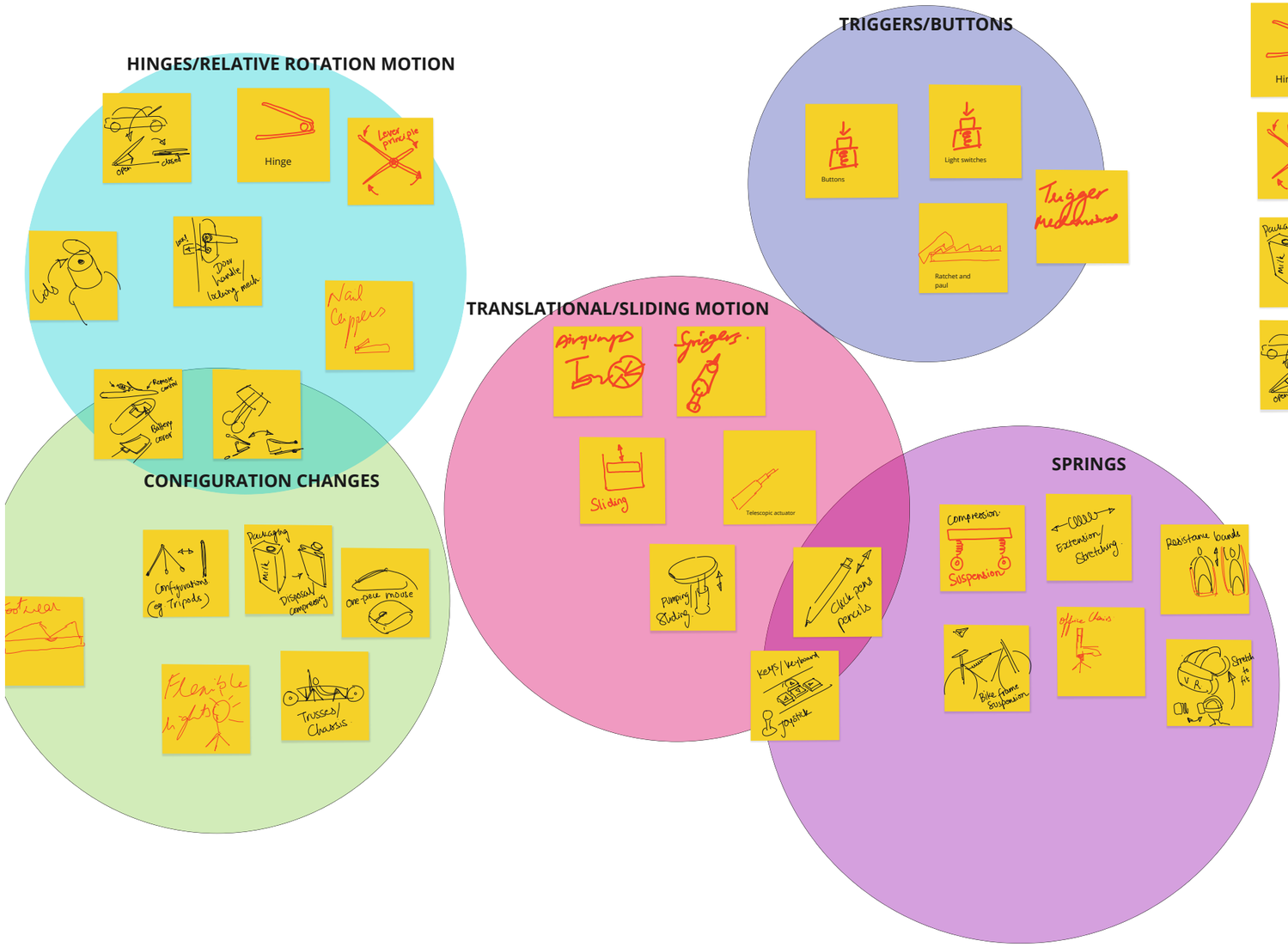
I designed my own custom compliant lego building blocks. We have made many such bricks at Precision and microsystems engineering. Please make an appointment with [Ali Amoozandeh Nobaveh](https://www.tudelft.nl/3me/over/afdelingen/precision-and-microsystems-engineering-pme/people/junior-research-staff/amoozandeh-nobaveh-ali) from the Mechatronic system design group if you would like to take a look at them. They are essentially two small lego technic bricks with slits sawed into them. We then glue a small spring steel plate in between the bricks. We have also experimented with wire springs. Please find attached a couple of examples of lego demonstrators. Basic compliant mechanism building blocks are thus essentially straight plate springs (3DOF) of various lengths (to get distributed compliance and short ones for lumped compliance) and wire springs (5DOF)

If you mean design rules for bistable mechanisms then I would say that you would have to create an elastic instability. At the unstable equilibrium usually there is a bifurcation which results in two stable equilibria. Creating such an instability requires preloading (can be in the motion direction itself (i.e. my designs you've seen) or perpendicular to the motion direction (i.e. the bistable lego demonstrators attached).

What is important for preloading is that the boundaries, the frame around the flexural device if you will, are sufficiently stiff. If they are not, you may lose the bistability altogether. The most commonly used bistable compliant mechanism is I would say the chevron type device, and there have been many variations on this design (more flexural elements, curved beams, lumped/distributed compliance etc.), you can easily find plenty of them in literature and there are also some parametric studies that identify the bistable region in it's parametric space (not all dimensions of a chevron type device lead to bistable behavior). Besides that you can also easily create bistability with normal springs if you preload them, i.e. preloaded spring on a cart is bistable. Or a combination of compliant and rigid body (partially compliant mechanisms). What sometimes happens when you don't design compliant mechanisms to be properly constrained (overconstraint) is that misalignment may render your device bistable.

Appendix C : Grouping Product features with a functionality Designer



Introduction :
This activity aimed at understanding the most common mechanisms a product designer must deal with in a project.

Method :
At first a number of mechanisms were listed in a small brainstorm session of 30mins. Once the brainstorm session was done the mechanisms were grouped under themes.

Result :
The themes that emerged were Hinges, buttons, configuration changes(eg open and close), springs. This inidicated the most common use of mechanisms in products.

Appendix D : The generative design workshop experience

Students learn similar principles but get to create unique outcomes

Low thresh hold to achieving the initial tasks improves engagement amongst students

There is a need to understand numerical values experientially eg what does 10N force result to in real life?

They need to understand what learning a skillset could result in eg generative design achieves light weight structures which corresponds to

Date : June 6th 9-4pm

Introduction :

In order to understand the context of an IDE workshop I was given an opportunity to assist a workshop that was led by an expert. This was a good opportunity to learn what is working and what could be better in a learning experience that aims at introducing students to engineering skills. The topic of the workshop was "Designing light weight structures". My role during the course of the workshop was that of a facilitator.

Observations :

The workshop was structured as below :
1)Introduction to tool/software and the industry(Passive)
2) Light weight design lecture(Passive)
-break-
3) Exercises with the software tool
4) Reflection and assessment.
The interest in the topic was very high.

A few of the students were totally uninitiated to the topic but were very curious to learn something new.

The most important thing that I noticed was that there was little room for people to interact with each other and discuss their own approaches amongst each other. There wasn't equal participation from all learners.

The level of participation could have been better, also people were more eager to come forward and to show what they've come up with and how they did achieve.

There was a lack in experiential knowledge when it came to understanding the values that needed to be put into the simulation software example : Static forces.

At first a simple exercise was given so the students could warm up to it and then more complex exercises were attempted.

The core purpose of learning the skill was established through the lecture on light weight design.

The workshop ended with a refelction session and let participants explain their work.

Conclusions :

1) The premise of the workshop must be set up, the stage must be set for the learner to be able to pick up the skill and why he should do that.
2) The facilitator/coach must be on top of the activity and must be able to guide the learners.
3) The learners come out of the workshop with their own creation that is unique to them. This givees them a sense of achievement and a sense of learning.
4) Equal participaion from all learners must be encourageed in order for them to learn from each other.
5) The focus of the acctivities must be to convert information into tangible understanding from the very start and to be able to build on it.
6) The workshop gave them a body of work that they could show off in their portfolio.

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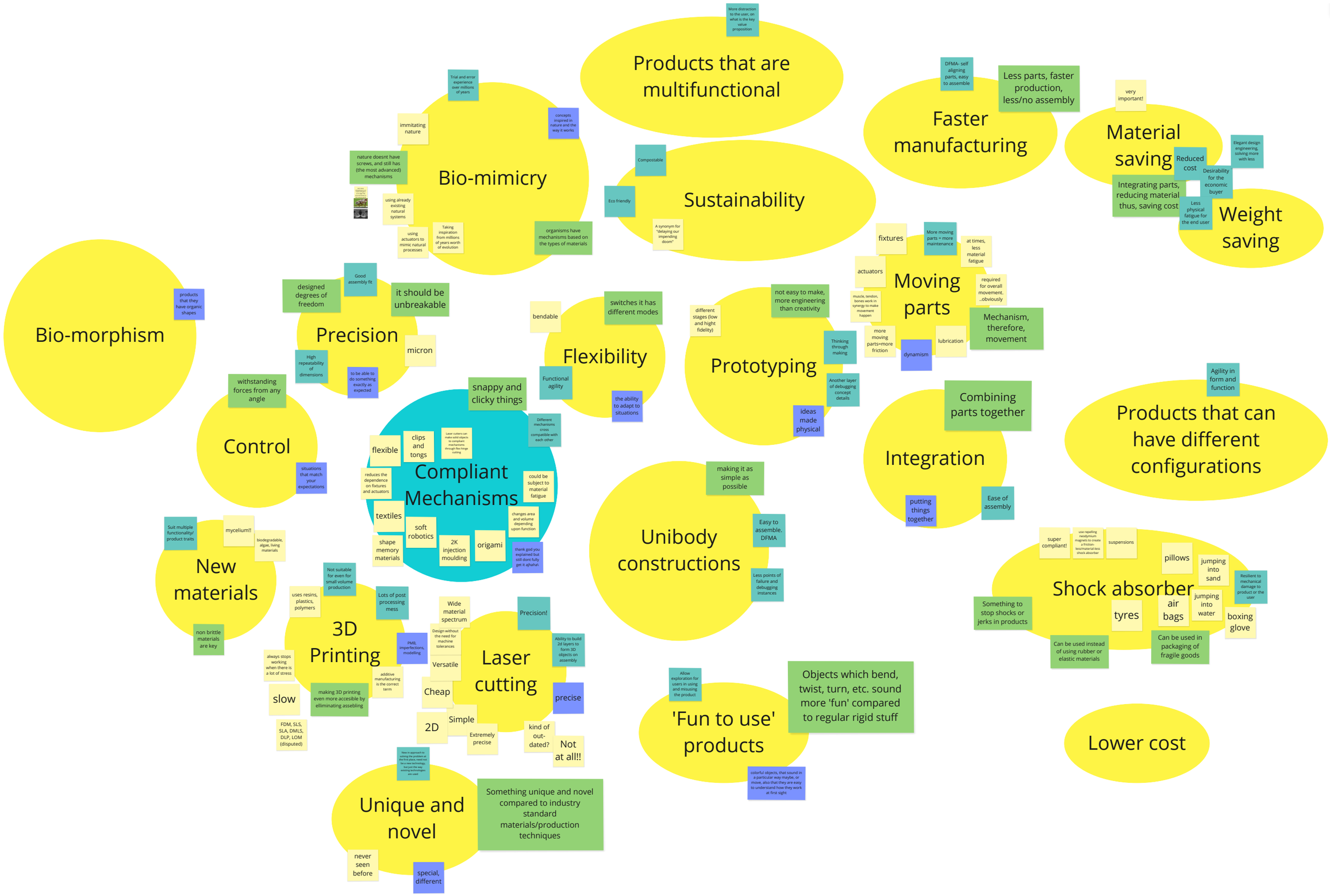
Appendix E : The word association activity with designers and questionnaire



Compliant Mechanisms for designers questionnaire

This is an initial step in understanding the interest from designers in incorporating principles of compliant mechanisms in their respective projects.

1) Are you interested about compliant Mechanisms?Why? *

Yes, if it brings, cheaper, simpler or more durable products onto the market.

2) What are you interested in understanding the most about incorporating flexibility in your rapid prototyping toolkit? *

The functions it can have similar to old fashion mechanisms, with the added benefits on top or to discover.

3) What challenges do you foresee if you have to acquire the skill of compliant mechanisms? *

A lot of trial and error, which takes time you might not have while rapid prototyping.

4) How do you think knowing about compliant mechanisms or flexible structures could help with your rapid prototyping skills? *

Make it simpler to assemble, less parts needed with similar functionality.

5) How would you envision implementing a compliant mechanism in your project right now? (Mention steps 1) 2) 3)) (At what stage of prototyping?) *

No project at the moment.

Compliant Mechanisms for designers questionnaire

This is an initial step in understanding the interest from designers in incorporating principles of compliant mechanisms in their respective projects.

1) Are you interested about compliant Mechanisms?Why? *

Yes. Interesting topic which can help create unique solutions, functionality, products which benefits for design, production, sustainability, etc.

2) What are you interested in understanding the most about incorporating flexibility in your rapid prototyping toolkit? *

What kind of traditional mechanisms and functionality can be replaced by compliant mech?
What materials are needed for compliant mech?
What manufacturing techniques can product these?
Rapid proto - what all 3D printing techniques can be used for compliant mech?

3) What challenges do you foresee if you have to acquire the skill of compliant mechanisms? *

Time commitment and lack of a dedicated project to work and explore this topic.

4) How do you think knowing about compliant mechanisms or flexible structures could help with your rapid prototyping skills? *

Diversifying my skillset and applying whenever the opportunity pops up.

5) How would you envision implementing a compliant mechanism in your project right now? (Mention steps 1) 2) 3)) (At what stage of prototyping?) *

1. Abstracting part of a product - simple functional parts like a hinge or other moving parts which can be combined into a single part.
2. Testing the function using 3D printing
3. Taking it forward to see its manufacturability on a larger scale.

Compliant Mechanisms for designers questionnaire

This is an initial step in understanding the interest from designers in incorporating principles of compliant mechanisms in their respective projects.

1) Are you interested about compliant Mechanisms?Why? *

Yes, it seems a very simple replacement to usual hinge mechanisms. Easy to manufacture and less number of parts.

2) What are you interested in understanding the most about incorporating flexibility in your rapid prototyping toolkit? *

Simple back and forth retractable mechanisms.

3) What challenges do you foresee if you have to acquire the skill of compliant mechanisms? *

What force can it take? How many cycles can it last? It will need FEM analysis to detect the life of the product unlike the usual hinge or lever mechanisms which are easily estimated.

4) How do you think knowing about compliant mechanisms or flexible structures could help with your rapid prototyping skills? *

Easy to use movable joints between parts.

5) How would you envision implementing a compliant mechanism in your project right now? (Mention steps 1) 2) 3)) (At what stage of prototyping?) *

Probably as to use connections. Do not need to make conveyances for connections in different parts.

Compliant Mechanisms for designers questionnaire

This is an initial step in understanding the interest from designers in incorporating principles of compliant mechanisms in their respective projects.

1) Are you interested about compliant Mechanisms?Why? *

Yes. I am very interested in compliant mechanisms. My outlook into product design is all about simplicity and repair-ability. The use of compliant mechanisms as moving parts for products reduces the need for fixtures thus reduces the need for additional design requirements. I believe that when a product is made of a consistent material, the product at the end of it's life can be recycled easily (taking plastics as an example). However, products manufactured through 2K injection moulding are a nightmare to recycle.
Compliant mechanisms allow for certain dynamism in products usability and at times aesthetics sans complications. See: Girish's wooden handbags where laser cutting makes a stiff piece of plywood a flexible flap which also adds to the aesthetic. -> https://www.girishmalage.com/timberbags-1

2) What are you interested in understanding the most about incorporating flexibility in your rapid prototyping toolkit? *

Mechanism/ materials ability to withstand fatigue. A ballpark estimate of the number of movements the material/mechanism can perform before succumbing to fatigue. (example of my shampoo bottle cap breaking after X number of uses)

3) What challenges do you foresee if you have to acquire the skill of compliant mechanisms? *

Understanding a plethora of materials in combination with manufacturing techniques could be a challenge in the beginning.

4) How do you think knowing about compliant mechanisms or flexible structures could help with your rapid prototyping skills? *

Keeping a consideration about flexible structures while designing a product opens up a whole new path for possibilities. Incorporating the different aesthetic styles brought about by flexible/compliant mechanisms will have a considerable say in the matter of a product's form and function.

5) How would you envision implementing a compliant mechanism in your project right now? (Mention steps 1) 2) 3)) (At what stage of prototyping?) *

1) Concept design and sculpt a basic form.
2) Focus on the moving parts of the concept and create a more detailed mock-up accordingly.
3)Use existing materials like fabric, paper, silicone (dragon skin), lasercut flex hinges in wood to mimic the compliance, user experience and functionality of the product I intend to develop through this mock-up model.
4) Once the mock-up yields favorable results, begin designing the product as per the materials and aesthetics I have in mind. Consult material experts to design the product with the most favorable material tolerances.

Introduction :

It is of paramount importance to know what students of design, mostly from varied backgrounds understand and think of themes that did emerge through interviews and early research. In order to gain an understanding, a word association was initiated. Once designers took part in the word association activity they were asked to fill out a questionnaire to enquire their understanding of compliant mechanisms and their motivations in doing so.

Key Insights :

1) Compliant mechanisms open up the possibilites for industrial designers to newer possibilites with unibody constructions, fun and novel products, explore their understandings and possibilites with laser cutting and 3D printing.
2) It helps them in reducing the number of moving parts in products.
3) An understanding of compliant mechanisms could also give them design freedom in designing casing forms that integrate functions.
4) The challenges forseen concerns with the time involved in getting to the final design, no or little understanding of materials to use for specific designs that could limit applying the knowledge of compliant mechanisms.
5) The manufacturing possibilities with this approach would need to be studied to understand how designers could make use of it in rapid prototyping.

FRAME YOUR CHALLENGE METHOD WORKSHEET

Frame Your Design Challenge

The understanding of compliant mechanisms is only available in the engineering realm and product designers have very little understanding of the principles of flexible engineering. Designers however have an intuitive way of working with prototypes and so compliant mechanisms could help designers in reducing prototyping time, it could simplify (part integration) the product, have more form freedom and gain better clarity in the design direction of the product early on in the ideation phase of the project. This allows product designers to sketch tangible solutions from the get go.

1.Take a stab at framing this challenge as a question:

How do we introduce compliant mechanisms to designers so that they can make a fully functional prototype of a product in 4hours?

2. Now state the key outcome you're trying to achieve:

Designing for fun, intuitive engineering, playfulness in learning, tangible result to show for the skill transfer

3.Write down important aspects of the context or constraints that you need to consider:

These could be shifts that we need to see in the ecosystem around the user, or factors that are technological, geographic or time-based.

Learning experience - 4hrs, doing experience - 3 hours, reflection and discussion - 1 hour. Learner engagement through play for equal participation, tangible product outcomes to show skill transfer and for reflection.

4. What are some possible solutions to your design question?

Think broadly. It's fine to ... sentence is same as existing.

Play based learning workshops, blended learning online course, product demonstrators, puzzle demonstrators.

5. Does your original design question need a tweak? Try it again.

How might we teach compliant mechanisms(flexible engineering) designers so that they can make a fully functional prototype of a product in 8hours?

Appendix G - Co-creation session survey

What do you think of today?	Did you get to learn something new?	What did you miss? What could have been better?
I found new (faster one) momentum in the design process.	Yes... how co-creation sessions work, how to untangle your thoughts from caught ideas and explore, 'going through the design cycle multiple times (quickly)' and 'iterate more' are some of the significant aspects of the design process.	I think some pictures/boards that include references for complaint mechanisms (found in nature) would speed up the process of getting to a constructive/innovative model/concept by the end of the session.
Interesting session definitely. Liked that you broke it down in various parts and wasn't super strict on timing. Happy with the result that you end up with a better understanding of the topic and then try to apply it in a design. Curious about the first proto.	Yep. Various new mechanisms and applications of compliant mechanisms. General idea of the topic and some specifics like the 1:5 ratio.	Would've been nice if it could be more hands on. Like the paper models that Shreyas was building. But not sure how it can be done with this topic. Cardboard models? Foam? Clay? something can be done maybe

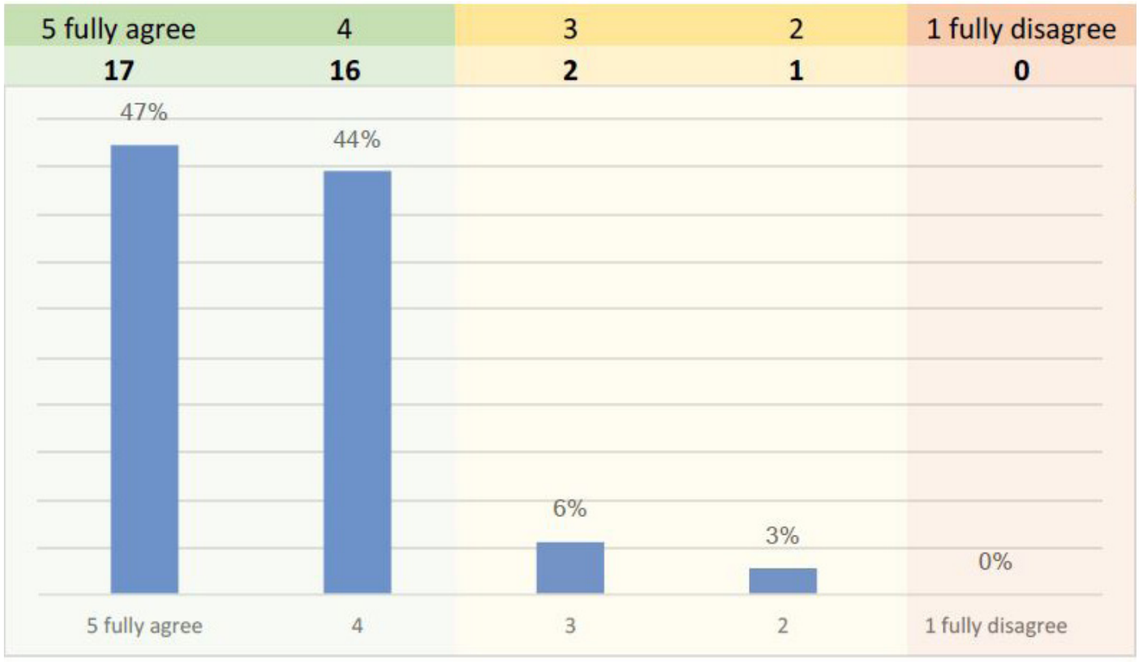
How engaged were you?	Was there any difficult time in the whole session?
on a scale of one to ten, I would say 9.	Yes! For me, rapidly analysing the conceptual models and generating a file for 3D prototyping was a bit difficult.
Actively engaged ~80% of the time. Sometimes in my own thinking zone.	Biomimicry is a difficult topic for me. Some more looking at images, videos, outdoors, etc. for inspiration would've helped.

IDE ACADEMY

QUIZ FEEDBACK: SEP 15 SKETCHING WITH TANGIBILITY

Score Distribution

The workshop helped me to get (more) familiar with the topic:



Respondents		*Attendees*
36	/	38

Avg. Score

4,36

IDE ACADEMY

QUIZ FEEDBACK: SEP 15 SKETCHING WITH TANGIBILITY

Comments

Any comments, tips or compliments for the workshop facilitator and/or the IDE Academy staff?

Learning how to design compliant mechanisms and seeing practical examples of them
Building your own mechanisms
Realy nice that we learned the basics of complient mechanisms in one day!
Getting to the rapid prototyping
Seeing that designing and printing your design in just a couple of hours can actually give you a working product. Also that you experience how complex mechanisms can be translated into something simple, made from one piece.
making the designed part with the 3d printer
Making a fully functional design. It came out well and the assignment was doable in the time given. Also very fun.
Very hands on workshop and it was great to see the results at the end and see what other groups came up woth
actually prototyping and printing in one day
Prototyping
getting to print your own design and test it
Getting to make our own design
Printing it yourself
Hand on workshop
Actually printing it and landing on a great design! (Pass holder)
Seeing the actual results working
One of the best ID academy workshops I've followed! (And I've already done 10). I really liked that within 1 day we could learn about these mechanisms and immediately apply it into our own tangible design
That we got to design and make something from start to finish in a day, really fun
You are really challenged to think it out by yourself
Seeing all the examples of tangible products
Making things, prototyping
Really practical
The modelling and 3D printing
sketching and seeing what was achievable in one day
Getting to know new methods for compliant design
Designing a mechanism yourself
having a first introduction with existing complient mechanism instead of digital
it was fun to thinking about different solutions to replace multiple moving components with parts consisting out of one piece and one material.
The enthusiasm of the person that gave it, he had a lot of energy and had not trouble motivating people
Being able to 3D print for the first time, and discover compliment mechanisms
Getting a working product is really satisfying. It is really inspiring. I'm excited to try making something like this again
That our design worked!!
Hands on session! Best way to learn, trial and error process and gives a better feeling. Would've been nice to do an iteration but we were just a bit too slow I guess :)
Being able to design and print/test our own mechanism

Appendix J - Reviews from /tudio Mango Workshop

How could the demonstrators (3D printed examples) be improved in introducing flexural design to the uninitiated?

5 responses

- It was pretty clear to me, but that's because I already have some basic knowledge
- It was quite good. more diversity in mechanism could help. Also real functional product that contain flexural elements would be nice.
- translation to real life applications
- Some real life examples more than only fany mechanisms
- The demonstrators itself were pretty self explanatory. I would have liked a bit more explanation on its application in the real world.

What was your experience of the workshop?

5 responses

- Fun. Learned some things along the way, like wall thickness ratio between stiff and flexible parts.
- A really nice introduction to this design field. Great to see what the result is after just a few hours. The theory part was quite short. For me you good go into more depth about this topic.
- It was inspiring to have a hands-on approach to the subject. I liked the fact that we could 3D print our idea's and evaluate it.
- Nice, cool to work with colleagues in a pressure cooker, good for team bonding
- Fun and hands-on! Some information on how you got where you are right now and how you would like to see this develop in the future would be nice.

The next stage of the development is to make this a toolkit. What main 4 elements would you prefer having in this toolkit?

5 responses

- examples and rules of thumb
- - Useful rule of thumbs that can be used when designing a flexural product. This is a good example: https://www.hubs.com/guides/injection-molding/
  - Physical examples that show the possibilities
  - Would be nice if the physical examples can be used as a kind of Lego blocks to build proof of concepts
- real-life applications, interesting mechanisms, examples of a compliant mechanism which is suitable for injectionmolding. As designers/engineers, we have to translate the cool compliant mechanism into something that can be mass-produced. Some examples where that translation is done would be super helpful.
- 1. Some real life examples 2. So's and Don't in verry short overview 3. various motions / sollutions that can be achieved 4. material guidelines, what material can I use
- Booklet/manual, example in 2D (spring; elongating & compressing), example with movement in 2 different planes(3D), example with rotation (3D),

How much do you think the workshop was worth individually for you? (Please specify in euros. This is the first step to understanding the value of a single session. If you're unable to put in a number then please specify in sentences or words the value it created for you eg: fun, team bonding, new tool or approach to work with etc))

5 responses

- fun and creative activity.
- I saw it as a kind of company outing that also teaches you something. It was fun to do and increased the team bond.
- I think it is a cool team-bonding experience. If offered as a payed workshop, I would say €100,- per person for a workshop that would last 6 hours. (more time to design, print, evaluate and iterate for a second print.
- 9 - scale of interresting, best part is team bonding €200-€250
- Fun teambuilding activity, interesting topic to be made aware of.

DESIGN FOR our future

5052

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name	Kadavil Abraham
initials	Thomas given name
student number	
street & no.	
zipcode & city	
country	
phone	
email	

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ○ DfI ○ SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ○ Honours Programme Master

specialisation / annotation: ○ Medisign ○ Tech. in Sustainable Design ○ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	Dr. ir. Tempelman, E.	dept. / section:	SDE/Dfs
** mentor	MSc. Persaud, S.M.	dept. / section:	SDE/PAD
2nd mentor			
	organisation:		
	city:	country:	

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Dr. ir. Tempelman, E. date 22 - 06 - 2021 signature

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: NVT EC

Of which, taking the conditional requirements into account, can be part of the exam programme NVT EC

List of electives obtained before the third semester without approval of the BoE

MVE

(X) YES all 1st year master courses passed

( ) NO missing 1st year master courses are:

name J. J. de Bruin date 23-06-2021 signature JdB

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: (V) APPROVED ( ) NOT APPROVED

Procedure: (V) APPROVED ( ) NOT APPROVED

remark: the projectbrief has been submitted late

comments

name Monique von Morgen date 6/7/2021 - signature

Personal Project Brief - IDE Master Graduation

Compliant mechanisms for designers — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 26 - 05 - 2021 05 - 11 - 2021 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Compliant Mechanisms have been around for sometime now, the knowledge of which exists in engineering but it is only until recently that it has been actively included/incorporated in products. A mechanism is said to be compliant when something useful is achieved by the bending of a flexible element.

Traditionally products are designed with stiff materials that are connected with hinges or sliding joints which are made of metal. This results in an increased number of parts, assembly costs rise up and product complexity increases.
The focus of designing compliance in products is in designing flexible and strong products. (Howell, L. L., Magleby, S. P., Olsen, B. M., & Wiley, J. (Eds.). (2013))

Compliant mechanisms show promise in the emerging areas of product design such as wearable devices in sports, prosthetics, robotics, everyday use products/tools, surgical equipments, furnitures.

The pros of compliant mechanisms include part integration, lower/no maintenance, easier replace-ability and serviceability of parts, higher fatigue tolerance, lower weight of product weight, simplified assembly, lower usage of space in a product. The cons include low level or no knowledge in early stages of design, non linear design approach.

Since these mechanisms are not rigid body based they could be integrated with apparels,they could be closer human contact. Compliant mechanisms have better control and mobility and so it could be closer to the users supporting their ergonomic needs. This is a motivation for industrial designers to incorporate compliant mechanisms early on in their product development.

This project would encompass understanding why product designers would want to use compliant mechanisms in the product development, outlining functional requirements when compliant mechanisms could be used and when it's a better idea to go the traditional route with rigid body mechanisms. What are the core principles that a designer must know to implement the knowledge of compliant mechanisms in his/her project. What tool/s could we equip product designers with to rapidly implement compliant mechanisms in their respective projects?

The context of this project is mainly in the IDE faculty, TU Delft and practicing designers in the industry. The main stakeholders are the Department of Sustainable Design Engineering and the IDE Academy. Sustainable design Engineering department focuses on providing Industrial designers with engineering knowledge for product development. The interest of the department is to develop an introduction to compliant mechanisms in association with the IDE Academy which focuses on introducing designers with skills they could use in developing products. These stakeholders mainly cater to the students interest in acquiring knowledge in skills they are curious about or about topics that are very new to them. Complaint mechanisms fits this space very well because there aren't any resources available to students and product designers except in the realm of core mechanical engineering.

The challenge that lie in this project is to be able to help students implement knowledge of Compliant mechanisms and design a product of their own in a time constraint of 8hrs.

Thus learning and teaching would be the main pillars of this project.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: An ongoing IDE Academy Workshop, TU Delft

image / figure 2: An example of compliant mechanisms in product applications(MSc Thesis, Patty De Groot,2021)

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The main question to be answered is "How can the knowledge of complaint mechanism aid designers and how do we simplify the understanding of compliant mechanisms so that it could be accessed and implemented by product designers in products during product development(technological feasibility to demonstration i.e from TRL 1-6).

Although the benefits of compliant mechanisms are known, the knowledge about how to implement these mechanisms in early stages of product development is scarcely available to product designers.

The solution space to the defined problem could range from product demonstrations, taxonomy of these mechanisms in products, frameworks, software tools, simplified educational content without having to deal with complex calculations, learning tools for rapid skill transfer.

Through the project a clear understanding of where designers could use compliant mechanisms would be made, furthermore simplified methods to implementation would be explored and recommended.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Goal of this project is to introduce compliant mechanisms to industrial designers. The approach to designing compliant mechanisms would be studied, core principles of developing compliant systems would then emerge. The next step would be to make these principles and knowledge relevant to product designers. The solution space would be a strategy/framework illustrated through demonstrations and a recommended learning path.

Why are compliant mechanisms relevant to product designers needs to be uncovered.

Then the challenges product designers face in developing mechanisms would need to be explored and studied. The challenges in implementation of compliant mechanisms early on in designs should be outlined.

The traditional route including methodologies such as pseudo-rigid body models and solving non linear equations of bending to designing compliant mechanisms in engineering would be studied and core principles outlined. It is then important to understand what methodologies would help product designers in developing mechanisms on their own.

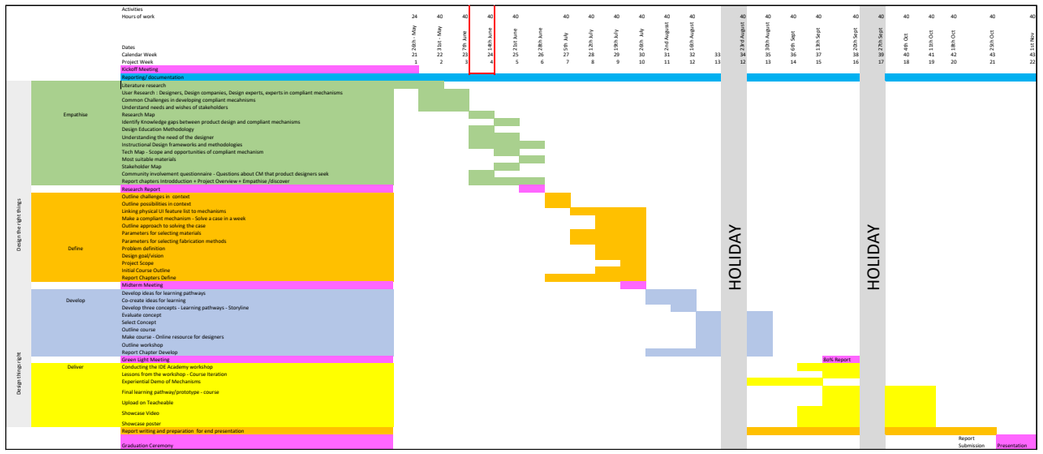
Once a certain understanding of the knowledge area and methods of implementation are understood, principles of instructional design would be studied in order to develop a learning journey for product designers to give them the tools necessary to develop a product implementing their knowledge of compliant mechanisms.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 26 - 5 - 2021

5 - 11 - 2021 end date



The project is preliminarily structured using the double diamond method(Design Council,2019).

The double diamond approach has four phases i.e discover, define, develop, deliver. The details of the project would emerge out of this main structure.

During the discover phase information about how compliant mechanisms are traditionally designed would be outlined. Then various stakeholders would be identified and their requirements would be understood via interviews.

In the define phase the problem to be tackled would be framed i.e for example challenges in developing these mechanisms, making it relevant to designers etc. Then HMU(how might we) questions would be asked to generate ideas to tackle the problem definition.

During the develop phase different ideas to learning pathways would be prototyped evaluated, promising ideas would then be made into concepts.

These concepts would then be iterated upon during the deliver phase, finally a workshop would be held at the IDE Academy as the validation of the conceptualized learning experience.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Personally, I'd like to showcase my ability to learn something from scratch and make it available for everyone to easily understand. Compliant mechanisms is a new topic and is something I've been very curious about. My competencies in research and to synthesize which I'd acquired through the master would be certainly put to use in this self initiated project.

A personal ambition with this project is to foray into the field of compliant mechanisms and instructional design. It is important to make a learning experience fun for the learner, in this project the learner being a product designer. The knowledge content being compliant mechanisms. The topic of compliant mechanisms is of importance to me because I'd like to foray into robotics with future projects and having an understanding of complaint mechanisms can put me in good stead in that regard. I'm excited to go into instructional design methodologies to come up with learning experiences that are both fun and engaging while transferring skill at a rapid rate.

In addition to compliant mechanisms I like to go into instructional design with this project because of my involvement in delivering engineering heavy courses to students of industrial design during the previous year as a teaching assistant.

As an industrial designer it is of paramount importance to be able to communicate well and present a complex scenario to the uninitiated, this is exactly what I'll be tackling with the project. The focus would be on learning and teaching.

Further more my personal leadership skills would be tested and improved, structuring and planning have always been my weak points and I would be focused on improvising these skills through this project.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.