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TEAM: a Tool for Eco Additive Manufacturing to optimize environmental impact in early design stages

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1. Literature Review

2. TEAM: Tool for Eco Additive Manufacturing
   A. Requirements specifications
   B. TEAM development

3. Experiment
   A. Protocol
   B. Results
1. Literature Review

AM & Sustainability

AM is promising for sustainable manufacturing and sustainable design
(Despeisse & Ford, 2015)

AM & Product design

Using AM to produce near net shape workpieces can substantially reduce lead time, cost, and material waste.
(Thompson, Moroni, Vaneker, Fadel, Campbell, Gibson, Bernard, Schutz, Graf, Ahuja, & Martina, 2016)

AM upsets the design paradigm and offers wide possibilities for product innovation
(Laverne, Segonds, Anwer, & Le Coq, 2015)

AM offers a high design freedom due to four possible complexities available in a same product
(Gibson, Rosen, & Stucker, 2015)

The production phase of a product manufactured with AM is the most influential on the environmental impact
(Barros, Mansur, & Zwolinski, 2017)

Designers often waste material due to the multiple trial-and-error iterations required for fixing unqualified feature requirements

AM & Product life-cycle

How to make the environmental impact of AM use for prototyping as low as possible in the life-cycle of a new product?

Dilemma during Early Design Stages!
⇒ Focus on the new product sustainability but no consideration for the prototype’s one!

⇒ Using AM for prototyping has an impact on the new product life-cycle!
1. Literature Review

How to make the environmental impact of AM use for prototyping as low as possible in the life-cycle of a new product?

The **Design to Environment approach** requires:

- Increasing the **eco-efficiency of the product manufacturing**
- Improving the **eco-effectiveness of the design**

Two possibilities for integrating DTE considerations:

- Involving AM experts during the EDS
- Supporting the designer with specific tools

By assisting designers with a Tool for Eco Additive Manufacturing dedicated to an eco-efficient use of AM and an eco-effectiveness of the prototype design

2. TEAM: Tool for Eco Additive Manufacturing

A 3-months study to understand the use of AM machines during the EDS of innovation projects

**Default settings** are frequently selected whatever the prototype’s use is

**TEAM specification:**

- **Delivering adequate settings** compatible with a validation of the expected features and with a **sustainable manufacturing**
- **Delivering design rules** for the adaptation of the concept CAD into a feature CAD
2. TEAM: Tool for Eco Additive Manufacturing 2.B. TEAM development

- TEAM Tool START
  1. AM machine selection
  2. Product description
  3. Compatibility of the data
  4. Environmental strategy selection

- TEAM Tool STOP
  AM machine environmental consumptions

TEAM V1 Flowchart

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3. Experiment 3.A. Protocol

Objective:
TEAM user experience + Influence of AM and Eco-design knowledge

Panel:
28 participants working in EDS of new product development
Pluridisciplinary profils

Protocol:
TEAM handling (≈ 15min) + Questionnaire

Subjective evaluation:
Nielsen criteria: (Nielsen 1994)
Usability: Learnability + Satisfaction
Utility
Acceptability

6-points Likert scale + Non-mandatory open answers
3. Experiment 3.B. Results

Results:

<table>
<thead>
<tr>
<th></th>
<th>Learnability</th>
<th>Satisfaction</th>
<th>Utility</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean on the 6 points Likert scale</td>
<td>4.14</td>
<td>4.71</td>
<td>4.53</td>
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<td>Standard Deviation</td>
<td>0.93</td>
<td>0.91</td>
<td>0.92</td>
<td>1.03</td>
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</table>

Intermediate to high satisfaction level for the 4 criteria

⇒ TEAM is well accepted by users

Mann–Whitney U test for the grouping criterion “AM knowledge level”

<table>
<thead>
<tr>
<th></th>
<th>Usability Learnability</th>
<th>Usability Satisfaction</th>
<th>Utility</th>
<th>Acceptability</th>
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<tbody>
<tr>
<td>U de Mann–Whitney</td>
<td>47.5</td>
<td>63</td>
<td>45</td>
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<tr>
<td>W de Wilcoxon</td>
<td>257.5</td>
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<td>-1.87</td>
<td>-0.245</td>
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<tr>
<td>Z</td>
<td>-1.77</td>
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<tr>
<td>Asymptotic</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Exact significance</td>
<td>.029</td>
<td>.049</td>
<td>.079</td>
<td>.223</td>
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</table>

Mann–Whitney U test for the grouping criterion “Eco-design knowledge level”

<table>
<thead>
<tr>
<th></th>
<th>Usability Learnability</th>
<th>Usability Satisfaction</th>
<th>Utility</th>
<th>Acceptability</th>
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<tbody>
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<td>U de Mann–Whitney</td>
<td>76.5</td>
<td>48.5</td>
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<td>W de Wilcoxon</td>
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<tr>
<td>Z</td>
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<td>-1.212</td>
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<td>Asymptotic</td>
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<tr>
<td>Exact significance</td>
<td>.074</td>
<td>.068</td>
<td>.089</td>
<td>.285</td>
</tr>
</tbody>
</table>

No significant difference between groups (with or without AMK or EDK)

⇒ Skills don’t influence the answers

⇒ TEAM use doesn’t require skills

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