Interactive Teaching of PL Theory with a Proof Assistant

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ELTE | FACULTY OF INFORMATICS

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Problem: understanding formal theories is challenging for CS students

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Observation: active learning positively impacts student performance [1-3]

[1] Revell, A., & Wainwright, E. (2009). What Makes Lectures 'Unmissable'? Insights into Teaching Excellence and Active Learning. *Journal of Geography in Higher Education*, https://doi.org/10.1080/03098260802276771

[2] Freeman, S. et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS Proceedings of the National Academy of Sciences of the United States of America,* https://doi.org/10.1073/pnas.1319030111

[3] Prince, M. (2004), Does Active Learning Work? A Review of the Research. Journal of Engineering Education, 93: 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

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Our solution: introduction of **interactive theorem proving (ITP)** and labs

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Our current method of teaching

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Pen-and-paper approach to teach PL theory

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Formal semantics

Type systems

Type theory

Interactive theorem proving (ITP)

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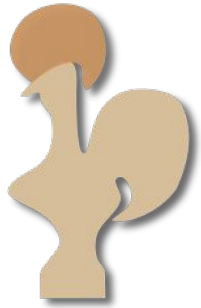
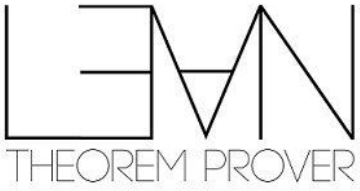
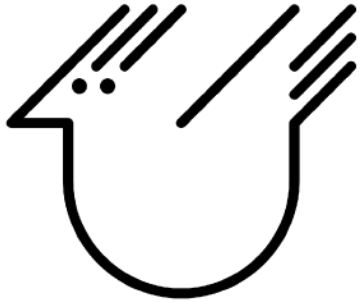
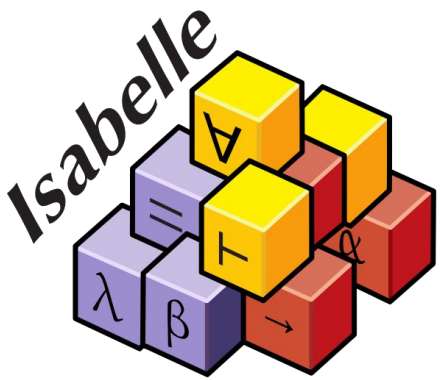
Proof assistants…









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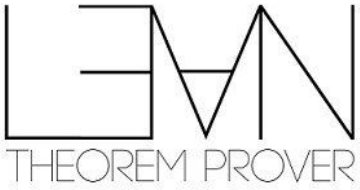

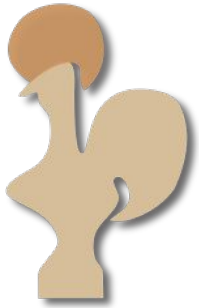

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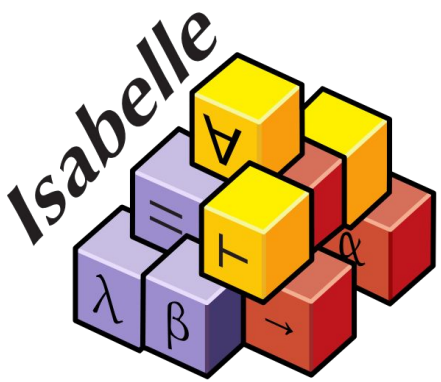
- guide users to construct proofs



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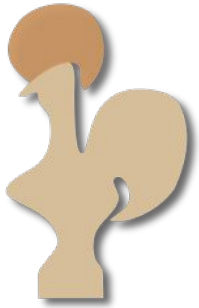

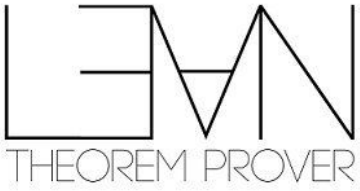

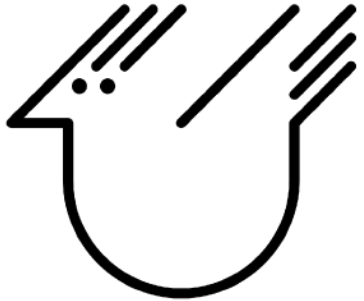

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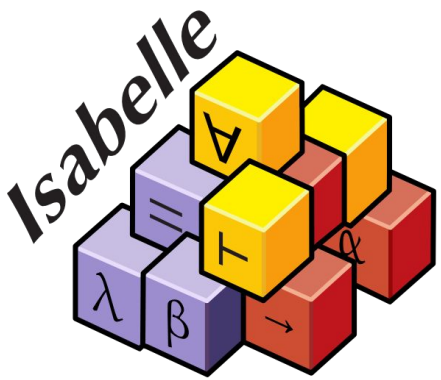

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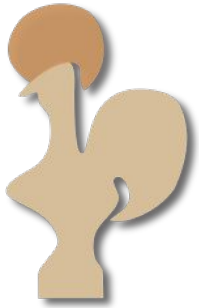

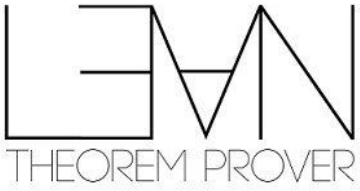

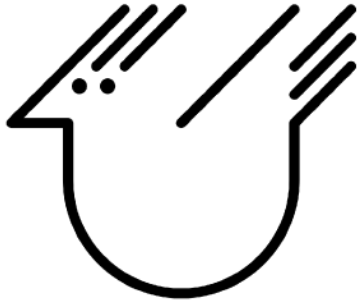

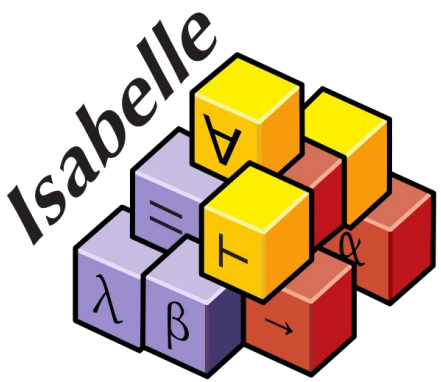

Proof assistants…

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- check the correctness of the finished proof
- are based on well-founded theories

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 1 From Coq Require Import PeanoNat.
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 3 Theorem plus_comm :
 4   forall n m, n + m = m + n.
 5 Proof.
 6   induction n; intros.
 7   * simpl. rewrite Nat.add_0_r. reflexivity.
 8   * simpl. rewrite IHn.
 9     rewrite Nat.add_succ_r.
10     reflexivity.
11 Qed.
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1 goal
m : nat
_____________________________________(1/1)
m = m + 0
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Students gain a deeper understanding of the material

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Time management - introductory classes

- Topics are left out
- Supplementary material
- Extensible definitions
- Homework assignments

Takeaways

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Our solution: introduction of **interactive theorem proving**

- ITP provides **immediate feedback**
- **Developing** formal **theory is programming**
- Proof assistants are emerging in industry too

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Goal: make PL theory subjects more approachable to students

Observation: active learning positively impacts student performance

Our so

- IT
- **D**
- Pr