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Build It Wrong, But Build It – A Bicycle Trek

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Abstract

The author initially became intrigued in the seeming mystery of bicycle stability in part as a result of the musings of Jones [1], and reported in *The Wall Street Journal* [2]. The author has spent forty years pondering numerous mysteries associated with the bicycle. A resulting activity came to being known as the University of Illinois Bicycle Research Project [3]. This paper provides an overview of the author's resulting four decades long bicycle trek. Using the concepts of empiricism along with open ended essay assignments to students, the author oversaw and directed the bicycle related research investigations of approximately 1,000 mechanical engineering undergraduate students. Moreover, the author performed some additional studies, often as sequels to the student investigations.

This paper endeavors to report on a selection of the most noteworthy contributions that resulted from the University of Illinois Bicycle Research Project. The paper's title makes reference to the concept of trial and error. While theory has incredible merits, complimentary information can be gained at a comparatively swift rate once the decision is made to tinker, build (and build crudely if necessary), and observe outcomes. The guideline to the students often became; "Build it wrong, but build it." A prior century of analytical thinking focused on the role of precession of the wheels of a bicycle as the crux of stability, and yet the bicycle industry simultaneously was going to considerable lengths to lighten bicycle wheels. Sales of bicycles with light weight wheels increased. Moreover, bicycles appeared to be vastly more forgiving and robust than suggested by extant theory.

Topics to be discussed include:

1. Precession cancelation and enhancement experiments
2. Front fork geometry and trail experiments
3. Rear-steered bicycle designs
4. Rocket bike push tests (with an asymmetrical rocket torque applied to the handlebars)
5. Steer torque and lean angle experiments on a bicycle ridden on marked circular paths
6. Musings on riding a bicycle on the moon, hence the predictions of bicycle dynamics in fractional gravity environments
7. Reduced scale model experiments of bicycles with gyroscope controlled steering
8. Designs to achieve a passive intuitive bicycle thereby eliminating the need for counter-steering
9. The passive SSTT (Stable Single Track Trailer) design challenge
10. The Anti-Wind Bicycle challenge

11. The non-existent bicycle block diagram dilemma

When all of the studies and experiments cited above are looked at as a whole, the results point to underlying truths as per the bicycle handling and dynamics. A bicycle remains upright by a combination or orchestration of mechanisms. The ease in riding a bike to maintain stability is made possible by a mixture of four dominant mechanisms; (1) rider skill in knowing to ease the bicycle's steering into the direction of fall, (2) the front steering configuration combined with a combined head angle and rake to create proper trail, (3) the role of precession that reinforces the turn of the front fork assembly into the direction of fall, and (iv) rider upper torso articulation. All four of these mechanisms, to varying degrees, work individually and in concert to make it easy to ride a bicycle. Moreover, extensive experiments demonstrate that none are necessary *per se* as rideable bikes demonstrate that each of the four mechanisms may be negated and yet the bicycle can still be ridden – and quite easily. As a consequence, two sayings have become associated with the ease of riding a bicycle – "Once you learn how to ride a bike, you never forget." "It's as easy as riding a bike."

In the author's extensive involvement in teaching thousands of children with disabilities to ride a bicycle, the instructions to the child boil down to three simple things – (i) pedal the bike, (ii) keep your head up and look forward, and (iii) smile. Of the three admonitions, the smile is perhaps the most important of all, for when a child doesn't smile this is associated with a high level of fear and anxiety. Fear and anxiety cause the body to be stiff as opposed to relaxed. Stiffness of the body brings with it a reduction in movement of the body joints, reflecting a reduction in the degrees of freedom. Conversely, a relaxed body tends to be more fluid, graceful and utilizes an increased number of body joints. As the body becomes more fluid, the energy required to perform a task is diminished.

The author concludes with an overview of the *Lose the Training Wheels* program now established in the United States [4, 5]. The goal of *Lose the Training Wheels* is to work with children with disabilities so as to allow the children to master the ability to ride a conventional two-wheeled bicycle.

References

[1] D. E. H. Jones, "The stability of the bicycle," *Physics Today*, 23(4), (1970), pp. 34-40.

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[3] R. E. Klein, "Using bicycles to teach system dynamics," *Institute of Electrical and Electronics Engineers, Control Systems Magazine*, **9**:3, (1989), pp. 4-8.

[4] K. J. Astrom, R. E. Klein and A. Lennartsson, "Bicycle Dynamics and Control," *IEEE Control Systems Magazine,* 2**5**:4, (2005), pp. 26-47.

[5] http://www.losethetrainingwheels.org