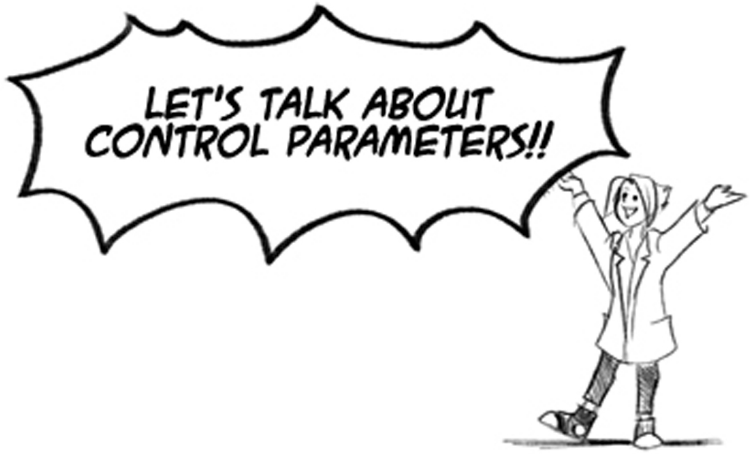
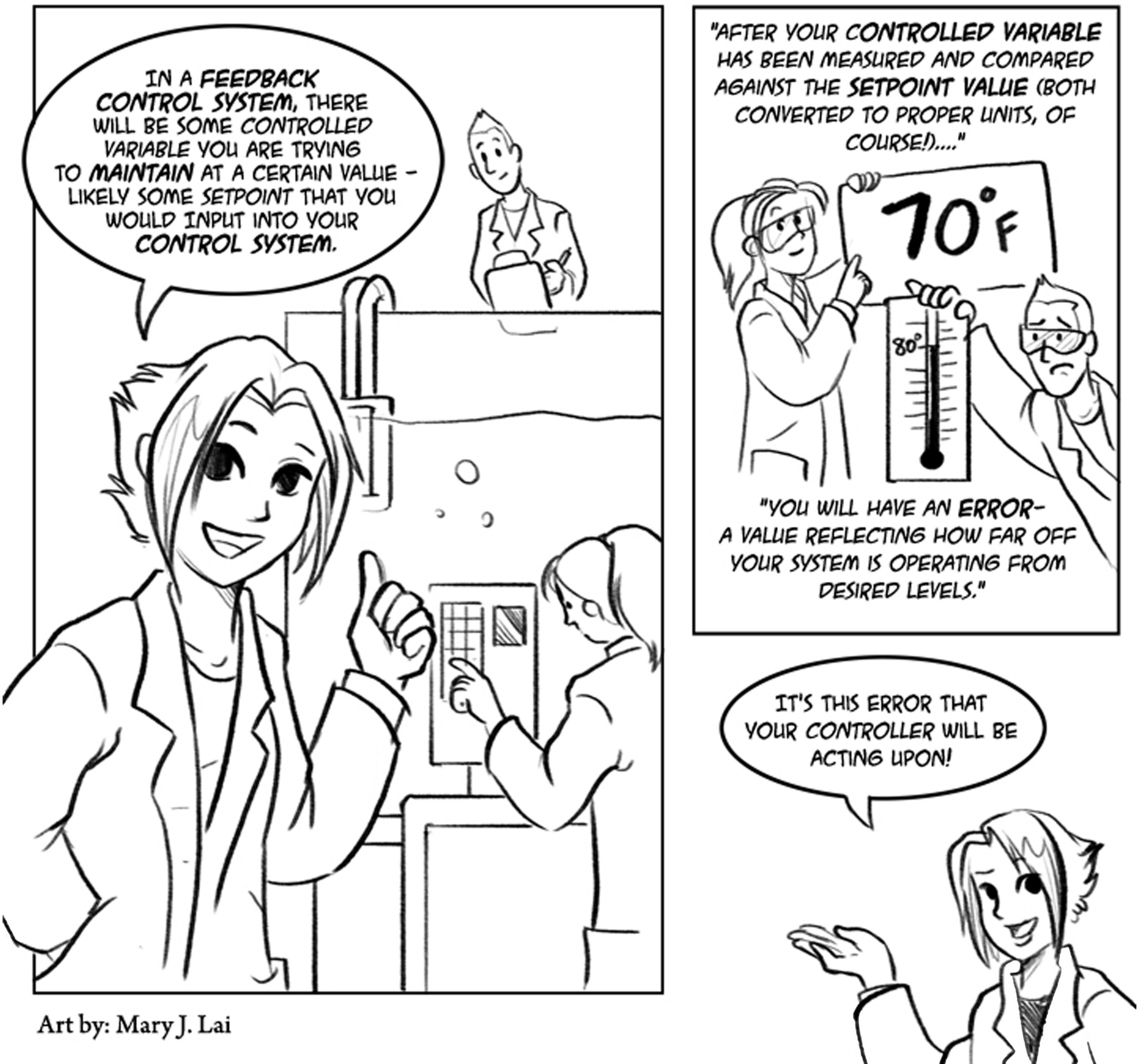
Feedback Controllers

Written by: Dante Shepherd





Art by: Mary J. Lai

Northeastern

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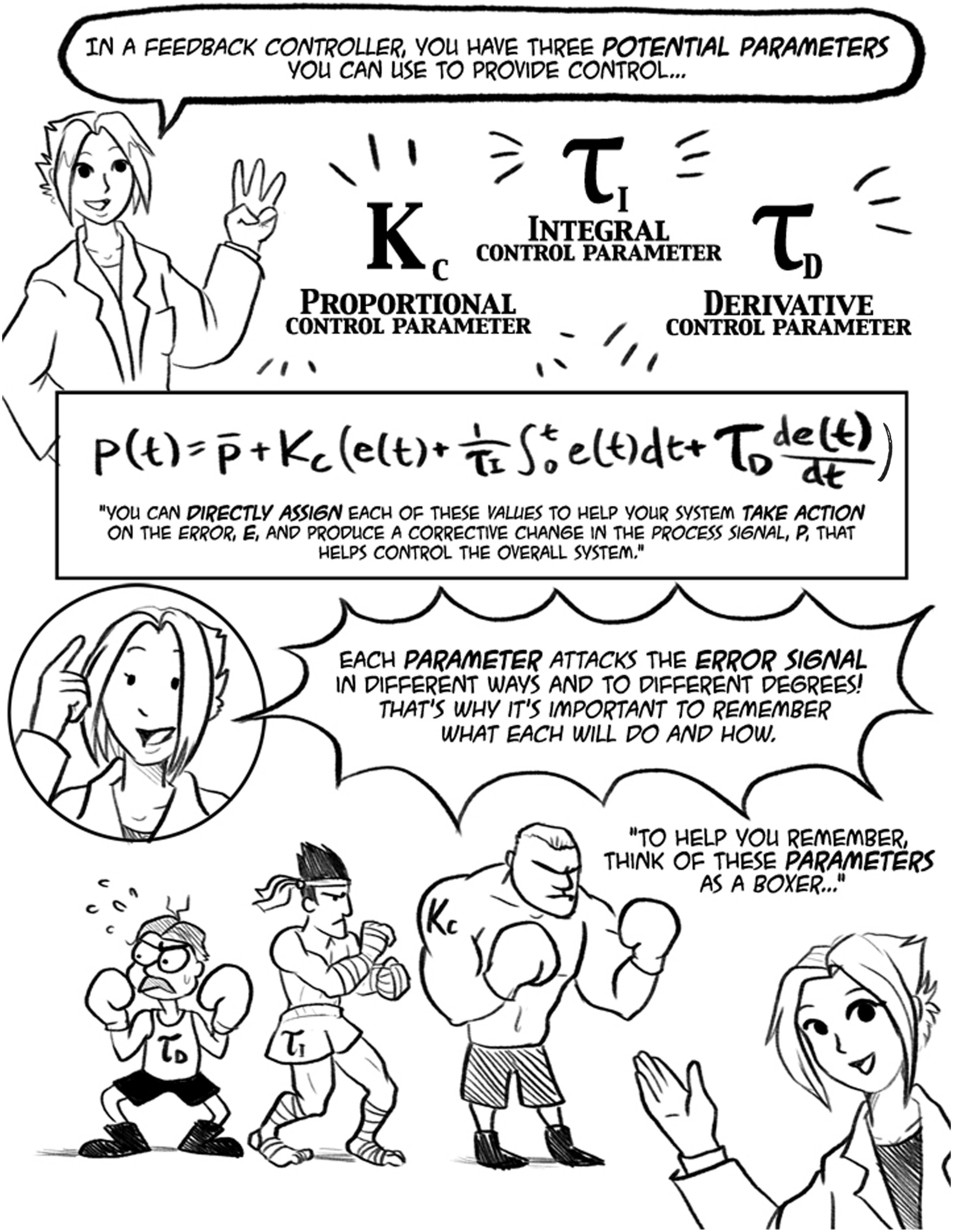

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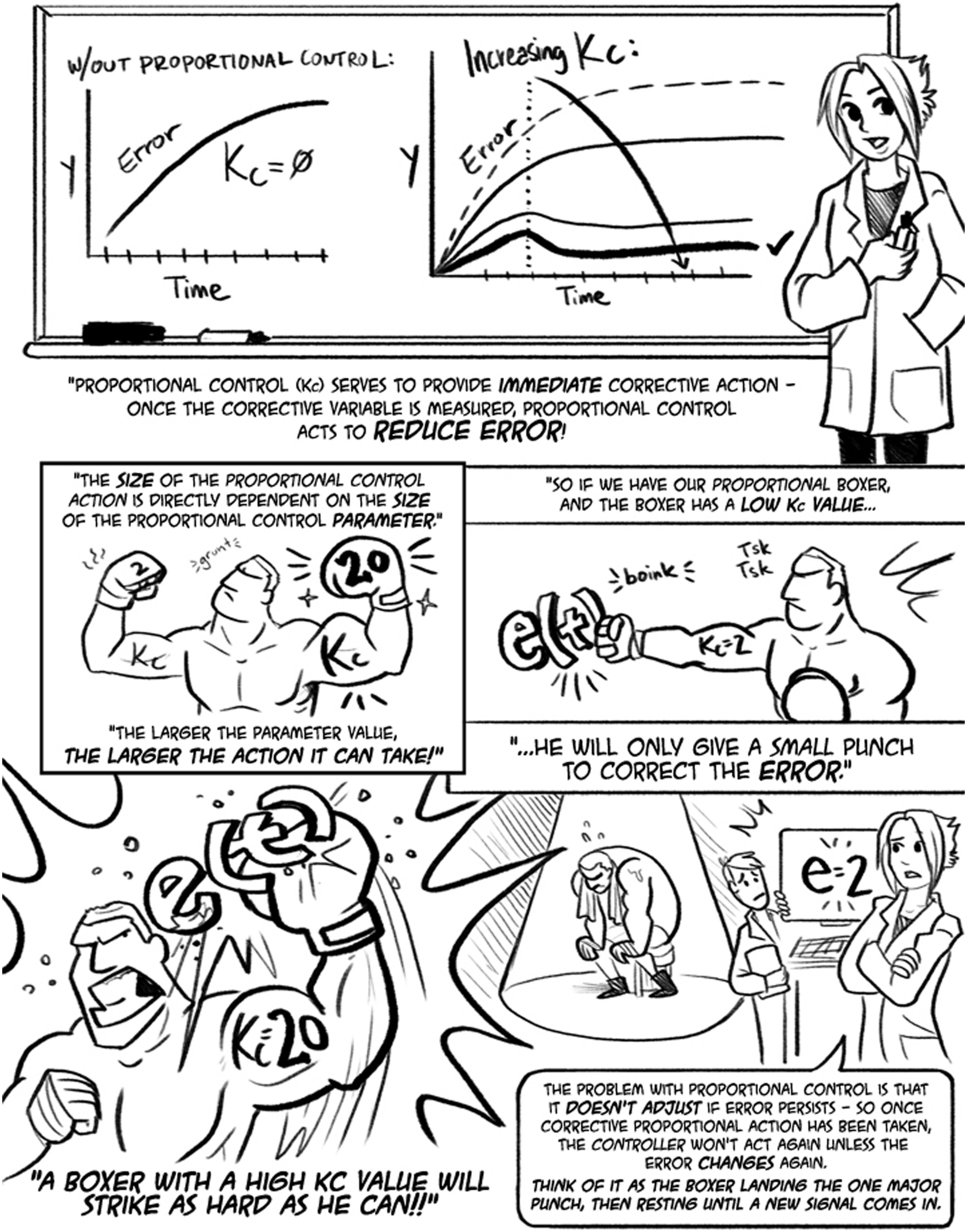
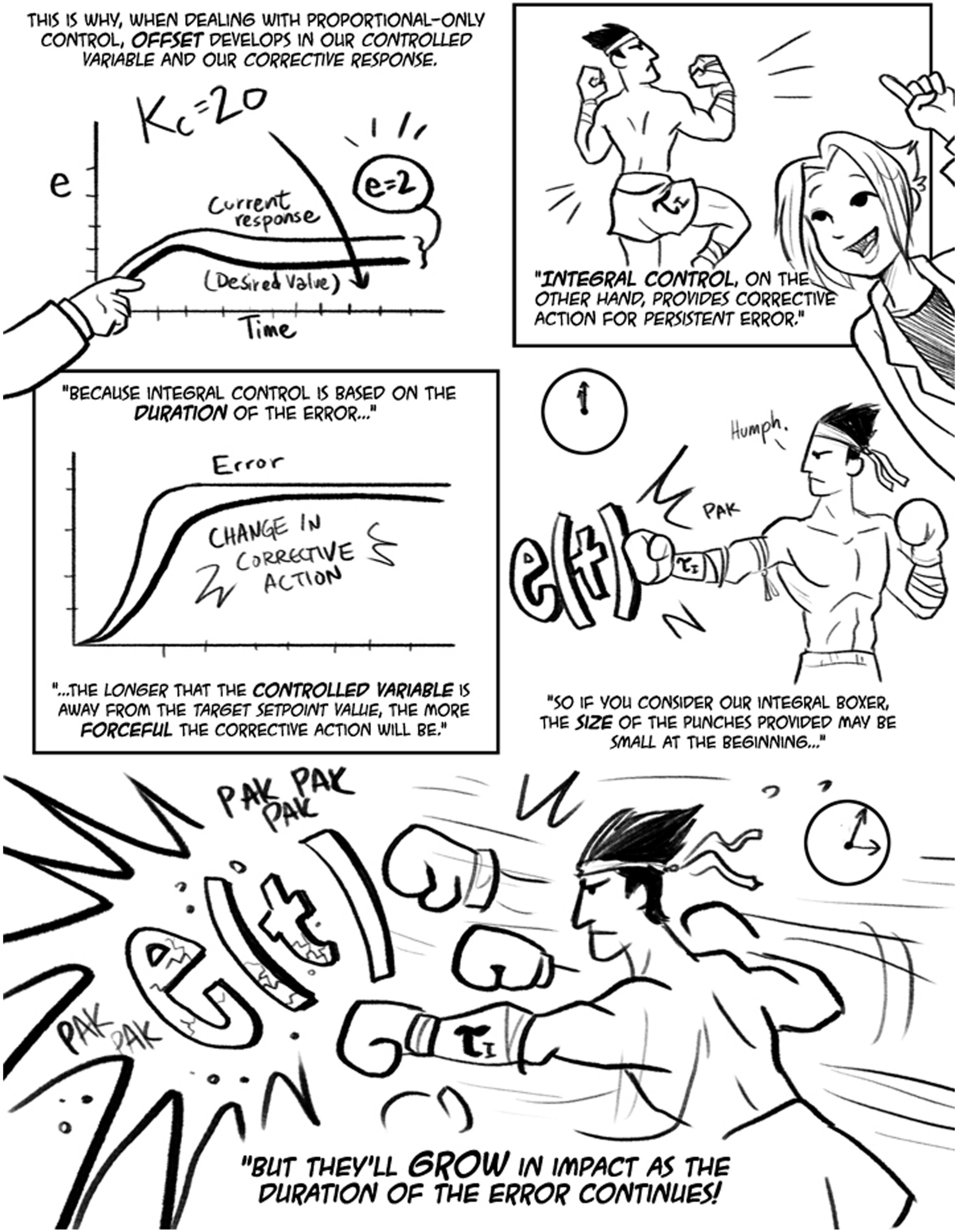
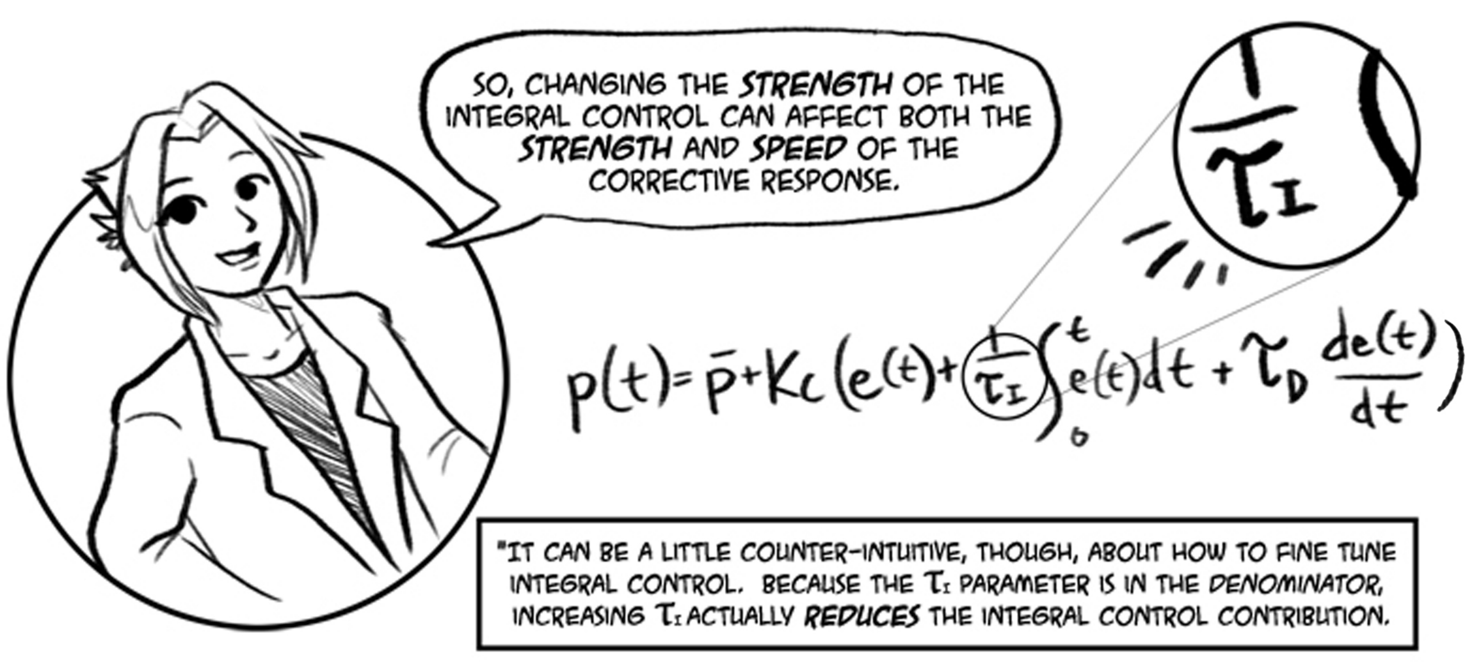
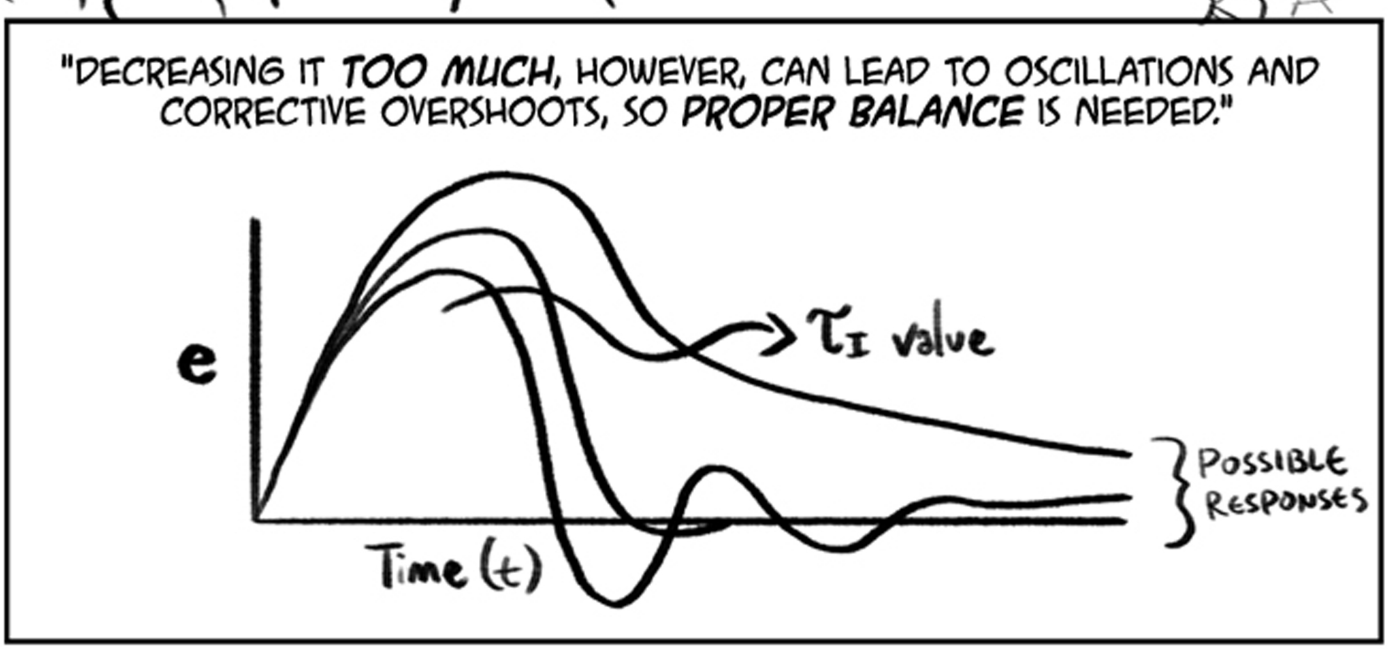

W/OUT PROPORTIONAL CONTROL:
Y
Error
Kc=Ø
Time
Increasing Kc:
Y
Error
Time
"PROPORTIONAL CONTROL (Kc) SERVES TO PROVIDE IMMEDIATE CORRECTIVE ACTION - ONCE THE CORRECTIVE VARIABLE IS MEASURED, PROPORTIONAL CONTROL ACTS TO REDUCE ERROR!
"THE SIZE OF THE PROPORTIONAL CONTROL ACTION IS DIRECTLY DEPENDENT ON THE SIZE OF THE PROPORTIONAL CONTROL PARAMETER."
2
grunt
20
Kc
Kc
"THE LARGER THE PARAMETER VALUE, THE LARGER THE ACTION IT CAN TAKE!"
"SO IF WE HAVE OUR PROPORTIONAL BOXER, AND THE BOXER HAS A LOW Kc VALUE...
boink
Tsk Tsk
e(t)
Kc=2
"...HE WILL ONLY GIVE A SMALL PUNCH TO CORRECT THE ERROR."
e(t)
Kc=20
"A BOXER WITH A HIGH KC VALUE WILL STRIKE AS HARD AS HE CAN!!"
e=2
THE PROBLEM WITH PROPORTIONAL CONTROL IS THAT IT DOESN'T ADJUST IF ERROR PERSISTS - SO ONCE CORRECTIVE PROPORTIONAL ACTION HAS BEEN TAKEN, THE CONTROLLER WON'T ACT AGAIN UNLESS THE ERROR CHANGES AGAIN.
THINK OF IT AS THE BOXER LANDING THE ONE MAJOR PUNCH, THEN RESTING UNTIL A NEW SIGNAL COMES IN.

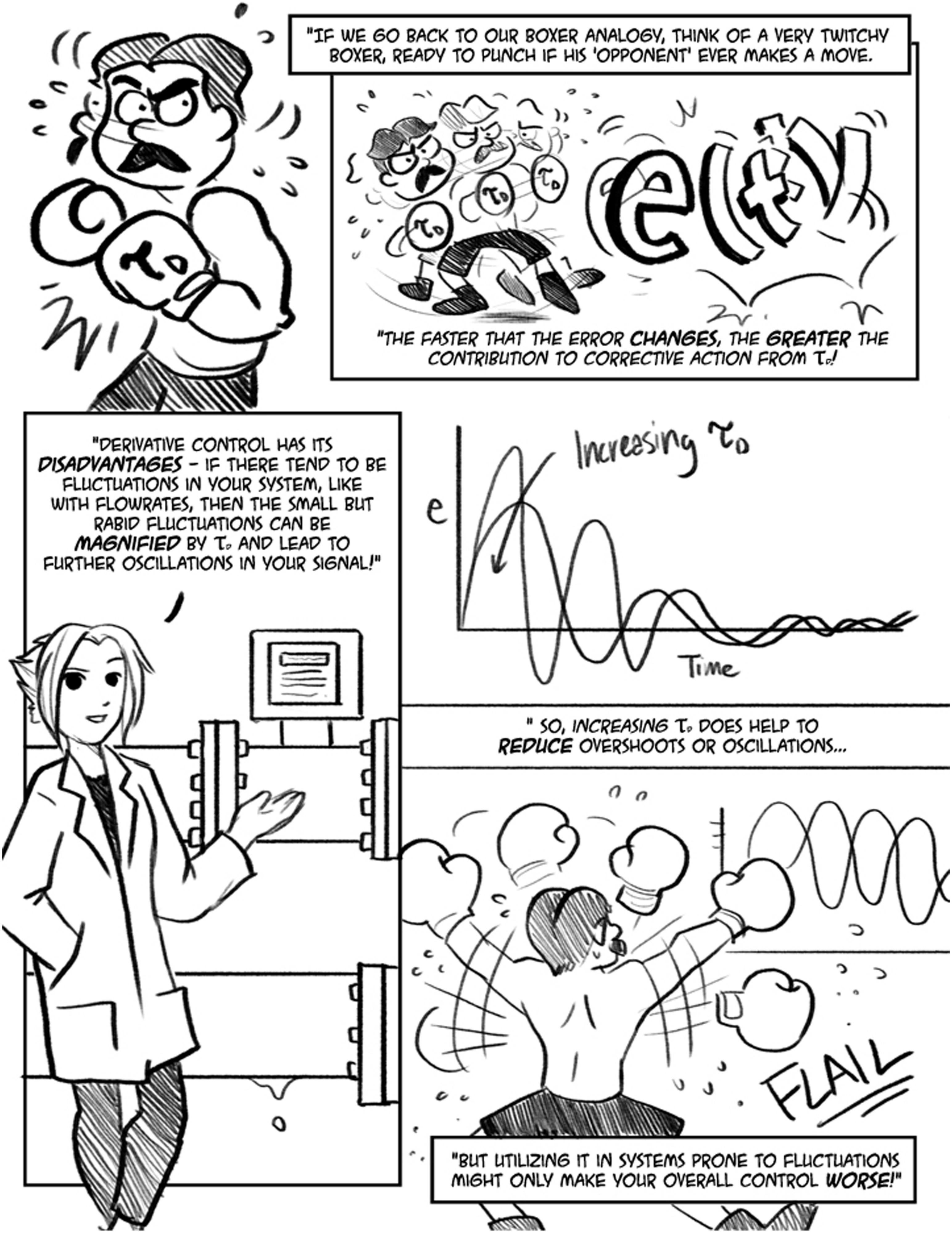

THIS IS WHY, WHEN DEALING WITH PROPORTIONAL-ONLY CONTROL, OFFSET DEVELOPS IN OUR CONTROLLED VARIABLE AND OUR CORRECTIVE RESPONSE.
Kc=20
e
e=2
Current response
(Desired Value)
Time
"INTEGRAL CONTROL, ON THE OTHER HAND, PROVIDES CORRECTIVE ACTION FOR PERSISTENT ERROR."
τI
"BECAUSE INTEGRAL CONTROL IS BASED ON THE DURATION OF THE ERROR..."
Error
CHANGE IN CORRECTIVE ACTION
"...THE LONGER THAT THE CONTROLLED VARIABLE IS AWAY FROM THE TARGET SETPOINT VALUE, THE MORE FORCEFUL THE CORRECTIVE ACTION WILL BE."
Humph.
PAK
e(t)
τI
"SO IF YOU CONSIDER OUR INTEGRAL BOXER, THE SIZE OF THE PUNCHES PROVIDED MAY BE SMALL AT THE BEGINNING..."
PAK PAK
PAK
e(t)
PAK
PAK
τI
"BUT THEY'LL GROW IN IMPACT AS THE DURATION OF THE ERROR CONTINUES!


SO, CHANGING THE **STRENGTH** OF THE INTEGRAL CONTROL CAN AFFECT BOTH THE **STRENGTH** AND **SPEED** OF THE CORRECTIVE RESPONSE.
$\frac{1}{\tau_I}$
$p(t) = \bar{p} + K_c \left(e(t) + \frac{1}{\tau_I} \int_0^t e(t)\,dt + \tau_D \frac{de(t)}{dt} \right)$
"IT CAN BE A LITTLE COUNTER-INTUITIVE, THOUGH, ABOUT HOW TO FINE TUNE INTEGRAL CONTROL. BECAUSE THE τ_I PARAMETER IS IN THE *DENOMINATOR*, INCREASING τ_I ACTUALLY **REDUCES** THE INTEGRAL CONTROL CONTRIBUTION.


REDUCING τ_I IS NECESSARY TO **REDUCE THE OFFSET** AND IMPROVE RESPONSE TIME WITH *INTEGRAL CONTROL*.
PAK
PAK
PAK PAK
PAK
PAK
PAK
PAK
e(t)
τ_I=2
τ_I=1


"DECREASING IT **TOO MUCH**, HOWEVER, CAN LEAD TO OSCILLATIONS AND CORRECTIVE OVERSHOOTS, SO **PROPER BALANCE** IS NEEDED."
e
Time (t)
τ_I value
POSSIBLE RESPONSES

"AT THIS POINT, WE HAVE MEANS OF CONTROLLING THE SIZE OF THE INITIAL CORRECTIVE RESPONSE TIME AND OFFSET FOR PROLONGED ERROR."
THE ONE ELEMENT OF POTENTIAL ERROR REMAINING IS IF DEVIATIONS IN THE CONTROLLED VARIABLE OCCUR SUDDENLY AND NEED MORE CORRECTIVE ACTION -
ACTION THAT IS FASTER THAN CAN BE PROVIDED BY INTEGRAL CONTROL!
"AFTER ALL, A DEVIATION OF 3° MAY NOT MEAN MUCH IF IT OCCURS OVER AN HOUR, BUT IF IT OCCURS OVER A FEW MINUTES?
"YOU'LL PROBABLY HOPE YOUR POWER PLANT HAS SOME GOOD PROCESS CONTROL AT WORK!!
WHICH LEADS US TO OUR FINAL PARAMETER, τ_D, FOR DERIVATIVE CONTROL.
"DERIVATIVE CONTROL SERVES TO DETECT THE RATE THAT ERROR DEVELOPS (HENCE, DERIVATIVE), AND THEN PROVIDES CORRECTIVE ACTION IN RESPONSE."
τ_D
τ_I
K_c


"IF WE GO BACK TO OUR BOXER ANALOGY, THINK OF A VERY TWITCHY BOXER, READY TO PUNCH IF HIS 'OPPONENT' EVER MAKES A MOVE.
τD
e(t)
"THE FASTER THAT THE ERROR **CHANGES**, THE **GREATER** THE CONTRIBUTION TO CORRECTIVE ACTION FROM τD!
"DERIVATIVE CONTROL HAS ITS **DISADVANTAGES** - IF THERE TEND TO BE FLUCTUATIONS IN YOUR SYSTEM, LIKE WITH FLOWRATES, THEN THE SMALL BUT RABID FLUCTUATIONS CAN BE **MAGNIFIED** BY τD AND LEAD TO FURTHER OSCILLATIONS IN YOUR SIGNAL!"
Increasing τD
e
Time
" SO, INCREASING τD DOES HELP TO **REDUCE** OVERSHOOTS OR OSCILLATIONS...
FLAIL
"BUT UTILIZING IT IN SYSTEMS PRONE TO FLUCTUATIONS MIGHT ONLY MAKE YOUR OVERALL CONTROL **WORSE**!"


"THERE ARE MODELS THAT CAN HELP TO DETERMINE WHAT THE OPTIMAL VALUES FOR Kc, τI, AND τD ALL ARE BASED ON YOUR OVERALL CONTROL SYSTEM – SOME OF WHICH ARE BASED ON THE SPEED OF THE CORRECTIVE RESPONSE, AND SOME OF WHICH TRY TO MINIMIZE CORRECTIVE OVERSHOOTS."
ZIEGLER & NICHOLS
Kc τI τD
P ONLY
PI CONTROL
PID CONTROL
TYREUS & LUYBEN (TLC)
Kc τI τD
PI CONTROL
PID CONTROL
IT'S UP TO YOU IN THE DESIGN OF THE CONTROL SYSTEM TO DETERMINE WHICH CORRECTIVE PARAMETER VALUES AND WHICH COMBINATION OF PROPORTIONAL, INTEGRAL, AND DERIVATIVE CONTROL IS MOST EFFECTIVE!
PROCESS CONTROLLERS ARE IN YOUR CORNER, SO TO SPEAK –
τI
Kc
τD
τD
USE THEM IN THE RIGHT WAY AND THEY'LL HELP KEEP YOUR ERROR TO A MINIMUM!